IEC/TR 62630

Edition 1.0 2010-03

TECHNICAL REPORT

colour inside

Guidance for evaluating exposure from multiple electromagnetic sources

IEC/TR 62630:2010(E)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

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 corrigenda or an amendment might have been published.

- Catalogue of IEC publications: www.iec.ch/searchpub

The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:

Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

IEC/TR 62630

Edition 1.0 2010-03

TECHNICAL REPORT

colour inside

Guidance for evaluating exposure from multiple electromagnetic sources

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE X

ICS 17.220.20; 33.050.10

ISBN 978-2-88910-776-6

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

GUIDANCE FOR EVALUATING EXPOSURE FROM MULTIPLE ELECTROMAGNETIC SOURCES

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) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. 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".

IEC/TR 62630, which is a technical report, has been prepared by IEC technical committee 106: Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure.

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

Enquiry draft	Report on voting
106/173/DTR	106/196/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 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. 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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This Technical Report provides guidance to IEC TC 106 project teams on how to evaluate the combined exposures from multiple electromagnetic (EM) sources in the frequency range 100 kHz to 300 GHz when *specific absorption rate* (*SAR*) and *equivalent power density* (*S*) are the relevant exposure metrics, as defined by the main international guidelines recommending limits on human exposure to EM fields.

SAR and power density are energy-intensive exposure metrics related to tissue heating. Other metrics have been defined in some exposure guidelines to regulate different effects, e.g., electro-stimulation. Guidance on evaluating exposure from multiple EM sources based on these other exposure metrics requires separate further study

This Technical Report considers the combination of exposures from multiple EM sources

a) which reside on the same electronic device (e.g. multi-band mobile phone);

b) arising from multiple devices (e.g. multiple base station antennas);

c) arising from temporally uncorrelated fields (e.g., transmitters operating in different bands);

d) arising from temporally correlated fields (e.g., adaptive (beam-steering) antenna arrays).

Only intentional EM-energy transmitters are considered.

NOTE Evaluation of spurious radiation from non-intentional emitters is addressed in electromagnetic compatibility (EMC) standards dealing with unwanted EM emissions from electronic devices. The guidance in this Technical Report is not specifically intended for combining exposures from non-intentional radiating sources, such as EM leakages from electronic devices that are not designed for purpose of radiated RF emission. However, it may be possible to use some of the methods in this Technical Report to evaluate multiple exposures when some of the sources are not designed to radiate EM energy, e.g. microwave ovens or RF welders and dryers.

This Technical Report establishes basic, rigorous techniques to estimate accurately and conservatively the combined exposure from multiple EM sources. In developing International Standards, it is anticipated that IEC Project Teams may deviate from or further evolve these techniques as required to better address specific device or evaluation requirements.

The techniques established in this Technical Report allow summing internal fields for the purpose of determining *SAR* and external fields for determining the power density. They do not describe how to perform the volume or surface averaging procedures that would be required to derive the compliance metrics (e.g., 10-g *SAR* or spatially-averaged power density) most commonly employed in national or international exposure guidelines.

This Technical Report does not define any test method or algorithm to determine product compliance with exposure limits, leaving that task to product compliance standards. Even though an effort is made to provide guidance consistent with the most referenced international exposure guidelines, the Technical Report does not establish or imply any requirement to follow any specific national or international exposure guideline since that is a regulatory matter. Rather, imposition of requirements depends on the policy of national regulators.

GUIDANCE FOR EVALUATING EXPOSURE FROM MULTIPLE ELECTROMAGNETIC SOURCES

1 Scope

This Technical Report describes exposure evaluation concepts and techniques for the overall exposure level in spatial regions and occupants caused by the simultaneous exposure to multiple narrowband electromagnetic (EM) sources. Throughout this Technical Report, it is assumed that the exposure evaluation occurs under static conditions, i.e., the source position and transmit-mode characteristics (e.g. emitted power, modulation scheme, etc.) of the device(s) under test do not vary significantly over the time required to carry out the evaluation using the chosen evaluation technique (e.g., field measurements).

The vast majority of wireless communication systems worldwide employ signalling schemes featuring narrowband waveforms, hereinafter defined as signal waveforms occupying a frequency band not broader than 10 % of its central frequency (justification of this threshold is provided below). For information, Annex A presents the operating system bands and channel bandwidths of several common wireless services.

Wide-band communication systems, e.g., ultra-wideband (UWB) systems employing impulsive waveforms with fractional bandwidth well in excess of 10 %, are relatively new to the marketplace, have experienced limited deployment so far, and are not typically regarded as significant contributors to EM exposure levels due to low transmit power levels.

NOTE Present exposure evaluation standards for fixed or mobile wireless communication devices, e.g., IEC 62209-1, are mostly tailored towards defining suitable techniques for narrowband waveforms. For instance, they recommend the use of scalar E-field or H-field sensors, e.g., miniature diode-detector probes, which typically provide accurate readings for narrowband waveforms, as defined herein. The paucity of UWB wireless communication systems, which have only very recently been introduced in the marketplace, as well as the low power levels associated with the corresponding signals to avoid interfering with coexisting electronic systems, has so far reduced the priority to standardize suitable evaluation techniques and to develop the relevant test instrumentation.

2 Normative references

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 62209-1:2005, *Human exposure to radio frequency fields from handheld and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)*

3 Terms, definitions and abbreviations

For the purposes of this document, the following terms and definitions apply.

3.1 Terms and definitions

3.1.1
air-interface
access mode
the radio portion of the link between the mobile station and the active base station. In the context of the Open Systems Interconnection Reference Model, the air interface operates at the Physical Layer and the Data Link Layer

3.1.2
antenna
aerial (deprecated)
that part of a radio transmitting or receiving system which is designed to provide the required coupling between a transmitter or a receiver and the medium in which the radio wave propagates

NOTE 1 In practice, the terminals of the antenna or the points to be considered as the interface between the antenna and the transmitter or receiver should be specified.

NOTE 2 If a transmitter or receiver is connected to its antenna by a feed line, the antenna may be considered to be a transducer between the guided waves of the feed line and the radiated waves in space.

3.1.3
antenna array
an antenna comprised of a number of generally identical radiating elements, arranged, oriented and excited to obtain a prescribed radiation pattern enhancing radiation in one or more directions and reducing radiation in other directions

NOTE 1 Typical examples include vertical arrays used in panel antennas at RBS sites.

NOTE 2 In most cases radiating elements are identical and congruent by translation or by rotation about an axis; moreover they are in general regularly spaced.

NOTE 3 In French, unless otherwise specified, the use of the term "antenne en réseau" implies that radiating elements are congruent by a simple translation.

3.1.4
antenna array, adaptive
smart antenna
antenna system incorporating active circuits associated with radiating elements whereby one or more of the characteristics of the antenna are automatically modified in a prescribed manner as a function of the received signal or changes in the electromagnetic environment

NOTE Recently, the technology has been extended to use the multiple antennas at both the transmitter and receiver; such a system is called a multiple-input multiple-output (MIMO) system. As extended smart antenna technology, MIMO supports spatial information processing, which includes spatial information coding such as Spatial Multiplexing and Diversity Coding, as well as beamforming.

3.1.5
antenna field regions
classification of the important spatial subdivisions of an antenna electromagnetic field. The subdivisions, at non-uniquely defined distances from the antenna, include the reactive near-field region adjacent to the antenna, the radiating near-field region (for large antennas commonly referred to as the Fresnel region), a transition zone, and furthermost, the far-field region, also known as the Fraunhofer region. *See also*: **near-field region** and **far-field region**

3.1.6
antenna gain
ratio, generally expressed in decibels, of the radiation intensity produced by an antenna in a given direction to the radiation intensity that would be obtained if the power accepted by the antenna were radiated equally in all directions

NOTE 1 If no direction is specified, the direction of maximum radiation intensity from the given antenna is implied.

NOTE 2 If the antenna is lossless, its absolute gain is equal to its directivity in the same direction.

3.1.7
antenna, radiation pattern
spatial distribution of a quantity that characterizes the electromagnetic fields radiated by an antenna

NOTE The distribution can be expressed as a mathematical function or as a graphic representation. The quantities that are most often used to characterize the radiation from an antenna are proportional to, or equal to, power density, radiation intensity, directivity, phase, polarisation, and field strength.

3.1.8
antenna, reconfigurable beam
shaped-beam antenna designed so that some of its radiation characteristics, such as the radiation pattern, can easily be modified, for example by telecommand

3.1.9
antenna, steerable-beam
antenna in which the direction of the main lobe can be changed either by controlling the excitation of the different elements or by mechanical means other than moving the entire antenna

3.1.10
average (temporal) power
rate of radiated energy transfer over a given time interval ΔT, given by

$$\bar{P}_{\mathrm{avg}}(t) = \frac{1}{\Delta T} \int_{t-\Delta T/2}^{t+\Delta T/2} P(\tau)\,\mathrm{d}\tau ,$$

where

ΔT is the (sliding) observation time window in seconds;

$P(t)$ is the instantaneous transmitted power in watts;

$\bar{P}_{\mathrm{avg}}$ is the average (temporal) transmitted power over the interval ΔT in watts

NOTE The average power is a function of the time window ΔT, assuming a constant value only if $\Delta T \to \infty$.

3.1.11
average (temporal) power density
instantaneous power density integrated over a specific time duration. The time duration could be source related, e.g., the source repetition period, or use related, e.g., the averaging time specified in exposure guidelines. Average power density is expressed in units of watts per square metre (W/m^2)

NOTE In speaking of average power density in general, it is necessary to distinguish between the spatial average (at a given instant) and the time average (at a given point).

3.1.12
basic restriction
restrictions on human exposure to time-varying electric, magnetic, and electromagnetic fields that are based directly on the applicable national or international exposure guidelines

NOTE In the context of this Technical Report, applicable *specific absorption rate* (*SAR*) limits represent the basic restrictions.

3.1.13
beamforming (digital)
method used to create the radiation pattern of the antenna array by adding constructively the phases of the signals in the direction of the targets/mobiles desired, and nulling the pattern of the targets/mobiles that are undesired/interfering targets. This may be done adaptively by digital signal processors to provide optimal beamforming

3.1.14
co-located transmitters
transmitters located in close proximity to each other so they can be considered as occupying the same location

NOTE The distance under which two or more transmitters may be considered as "co-located" depends on their respective power and frequency, as well as on the evaluation area or volume of interest. "Co-location", a property describing in general the relative proximity of two or more objects, i.e. occupying together a single location, may have impact on the approach required to evaluate the overall exposure.

3.1.15
collinear array

an antenna consisting of a linear array of radiating elements, usually dipoles, with their axes lying in a straight line

3.1.16
complex (electric or magnetic) field envelope
a complex vector whose components are the complex envelopes of the electric or magnetic field components. For time-harmonic fields, the complex envelope reduces to the field phasor

3.1.17
conductivity, (equivalent electrical)
scalar or tensor quantity the product of which by the electric field strength in a medium is equal to the electric current density. The unit of conductivity is siemens per metre (S/m)

NOTE For an isotropic medium the conductivity is a scalar quantity; for an anisotropic medium it is a tensor quantity.

3.1.18
correlated waveforms (in time)
signal waveforms yielding non-zero time-domain correlation integral at some time instant. For two power-limited signals $s_1(t), s_2(t)$, said integral is defined as

$$(s_1 \otimes s_2)(t) = \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{+T} s_1(\tau)^{+} s_2(t+\tau)\, d\tau ,$$

where the superscript $+$ represents the complex conjugate operation.

NOTE This definition is mathematically convenient since it allows exploiting some useful analytical properties of correlation and convolution integrals but requires knowledge of the signal waveforms over an infinite time. Such a requirement may be impractical when performing exposure measurements. As discussed in Annex B, B.2 and B.3, when dealing with wireless communication waveforms that typically feature very large bit-rates due to high data throughputs and processing gains, signal correlation may be accurately characterized over a few seconds at most.

3.1.19
correlated fields (in time)
electromagnetic fields, associated to distinct signal waveforms, yielding non-zero time-domain correlation integral at some time instant. For two power-limited field distributions $\mathbf{F}_1(\mathbf{r},t), \mathbf{F}_2(\mathbf{r},t)$, said integral is defined as

$$(\mathbf{F}_1 \otimes \mathbf{F}_2)(\mathbf{r},t) = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{+T} \mathbf{F}_1(\mathbf{r},\tau)^{+} \cdot \mathbf{F}_2(\mathbf{r},t+\tau)\, d\tau ,$$

where $\mathbf{r}$ is the location vector and the symbol $\cdot$ represents the inner product operation.

NOTE Observe that two fields are *uncorrelated* at locations where they are *geometrically orthogonal*. This property does not generally hold at nearby points unless the respective waveforms are uncorrelated (Annex B, B.2).

3.1.20
device
material element or assembly of such elements intended to perform a required function

NOTE In the context of this Technical Report, a device may comprise multiple EM sources.

3.1.21
dipole antenna
doublet
a symmetrical antenna composed of conductors usually rectilinear and energized by a balanced feed

NOTE The word "dipole" is sometimes used to describe antennas which do not conform in all respects to the above definition. In such cases, the word should be qualified, for example: "asymmetrical dipole". Common usage considers a dipole antenna to be a metal radiating structure that supports a line-current distribution similar to that of a thin straight wire, a half-wavelength long, so energized that the current has a node only at each end.

3.1.22
electric field strength
vector field quantity $\mathbf{E}$ which exerts on any charged particle at rest a force $\mathbf{F}$ equal to the product of $\mathbf{E}$ and the electric charge q of the particle

$$\mathbf{F} = q\,\mathbf{E} ,$$

where

$\mathbf{F}$ is the vector force acting on the particle in newtons;

q is the charge on the particle in coulombs;

$\mathbf{E}$ is the electric field in volts per metre.

3.1.23
(plane-wave) equivalent power density
the normalised value of the square of the electric or the magnetic field strength at a point. The value is expressed in W/m^2 and is computed in terms of the electric or magnetic field as follows:

$$S = \frac{|\mathbf{E}|^2_{rms}}{\eta_0} = \eta_0 \,|\mathbf{H}|^2_{rms}$$

where η_0 is the free space wave impedance, approximately 377 Ω.

3.1.24
exposure evaluation
process of measuring or estimating the intensity, frequency (and duration of human exposure if required to compare with applicable exposure limits), field strength, power density or *SAR* associated with electromagnetic fields

3.1.25
exposure, partial-body
localised exposure of part of the body, producing a corresponding localised *SAR*, as distinct from a whole-body exposure

3.1.26
exposure, whole-body
exposure of the whole body

3.1.27
exposure quotient (EQ)
the evaluated exposure parameter related to the relevant compliance limit expressed as the energy-intensive fraction of the related limit at a given frequency

3.1.28
far-field region

that region of the time-harmonic field of an antenna where the angular field distribution is essentially independent of the distance from the antenna. In this region (also called the free-space region), the field has a spherical-wave character and, locally, a substantial plane-wave character, i.e., very uniform distributions of electric field strength and magnetic field strength in planes transverse to the direction of propagation. For larger antennas especially, the far-field region is also referred to as the Fraunhofer region

3.1.29
intended use
the reasonably foreseeable use of a device for the purpose intended, over its full range of applicable functions, in accordance with the instructions provided by the manufacturer, including instructions on installation, operating position and orientation

3.1.30
isotropic field sensor (probe)
electric field or magnetic field sensor whose response is independent of the polarisation and incidence angle of the incident waves

3.1.31
magnetic field strength
vector quantity $\mathbf{H}$ obtained at a given point by subtracting the magnetisation $\mathbf{M}$ from the magnetic flux density $\mathbf{B}$ divided by the magnetic constant μ_0:

$$\mathbf{H} = \frac{\mathbf{B}}{\mu_0} - \mathbf{M}$$

where

$\mathbf{B}$ is the magnetic flux density in teslas; a vector field quantity which exerts on any charged particle q having velocity $\mathbf{v}$ a force $\mathbf{F} = q\left(\mathbf{v} \times \mathbf{B}\right)$;

μ_0 is the magnetic constant (permeability) in henries per metre;

$\mathbf{M}$ is the magnetisation in amperes per metre; for the purposes of this document, we shall assume $\mathbf{M} = \mathbf{0}$ in exposed tissues and in air;

$\mathbf{H}$ is the magnetic field in amperes per metre

3.1.32
multiple-input and multiple-output (MIMO)
the use of multiple antennas at both the transmitter and receiver to improve communication performance. It is one of several forms of smart antenna technology

3.1.33
multi-band (transmitter or device)
a transmitter or device capable of operating in more than one frequency band

3.1.34
multi-mode (transmitter or device)
a transmitter or wireless device capable of operating in more than one air-interface, e.g., UMTS, GSM and WLAN

3.1.35
narrowband electromagnetic source

source of electromagnetic field emissions whose occupied bandwidth is 10 % or less than its centre frequency

NOTE The terms narrowband, broadband, ultra-wideband have been used with different meanings and interpretations for different wireless products, technologies and markets. Therefore, the present definition is explicitly intended to be applicable within the context of this Technical Report.

3.1.36
near-field region
a region in the time-harmonic field of an antenna, located near the antenna, in which the electric and magnetic fields do not have a substantially plane-wave character, but vary considerably from point to point

NOTE The term is only vaguely defined and has different meanings for large and small antennas. It is further subdivided into the reactive near-field region, which is closest to the antenna and contains most or nearly all of the stored energy associated with the field of the antenna, and the radiating near-field region. If the antenna has a maximum overall dimension that is not large compared with the wavelength, the radiating near-field region may not exist. For antennas large in terms of wavelength, the radiating near-field region is sometimes referred to as the Fresnel region on the basis of analogy to optical terminology.

3.1.37
occupied bandwidth
width of the occupied band of an emission

3.1.38
peak spatial-average *SAR*
the maximal value of the local *SAR* averaged over a specified volume or mass, e.g., any 1 g or 10 g of tissue in the shape of a cube. *SAR* is expressed in units of watts per kilogram (W/kg)

3.1.39
phantom, (head or torso)
in the context of this Technical Report, a simplified representation or a model similar in appearance to the human (head or torso) anatomy and composed of materials with electrical properties similar to the corresponding tissues