ICES

International Committee on Electromagnetic Safety

Approved Minutes

IEEE/ICES TC95 Subcommittee 3

and

IEEE/ICES TC95 Subcommittee 4

Sunstar Park Hotel

Davos Switzerland

Saturday, 20 June 2009

9:00 AM – 5:00 PM

1. **Call to Order:**

   The meeting was called to order by SC4 Co-chairman Ziskin at 0910 h. Chair advised that the fee for the meeting is $155 US or €120. Lunch will be provided by the hotel at an additional fr.22. A list of payments received was not yet available.

2. **Introduction of those Present:**

   Each of the attendees introduced him/herself. (See Attachment 1 for list of Attendees.)

3. **Approval of Agenda:**

   The secretary (Petersen) is in Japan; David Black agreed to record the minutes of this meeting. Although this is a joint meeting of SC 3 and SC 4 neither SC3 Co-chairs were present; Thansandote was deputized as acting SC3 Co-chair for this meeting. Following a motion by Ziskin and a second by Chou, the agenda was approved (Attachment 2).

4. **Approval of the Minutes (December 2008 Meeting):**

   Following a motion by D'Andrea and a second by Thansandote, the minutes of the December 2008 SC3 and SC4 meeting were approved without modification.

5. **Secretary's Report:**

   To be presented on Sunday

6. **Chairmen's Reports:**

   a) SC3/SC4 Activities:

   Ziskin explained that major SC3/SC4 activity going forward will be to combine C95.1-2005 and C95.6-2002 into a revision of C95.1 that will apply over the frequency range of 0 Hz to 300 GHz. A new editorial working group has been formed to begin work on the revision—the working group is chaired by Chou.

   b) Presentation from Malaysia:

   Dr Pirunthavany Muthuvelu (Vany) gave a well-recived presentation on the legislative situation in Malaysia (Attachment 3). Included in the presentation were descriptions of how the precautionary priniple will apply and also concerns over interference with medical devices (EMI). Morrissey elaborated on the interference issue and Ziskin led a discussion on the precautionary principle.

c) New ARPANSA (Australia) Standard ELF-3 kHz:

Anderson presented information about the new ARPANSA limits (Attachment 4). He pointed out that the low frequency limits are based on the internal E-fields described in Dimbylow's work. Also precaution plays a major part in the approach, which is causing concern by industry regarding the cost of compliance.

Chou asked about magnetic flux density limits, believed to be between the ICNIRP and IEEE values. He noted that in Europe there are issues with higher levels of exposure, and it is important to define rules on safety margins and identifiable consequences.

d) Activities of ICNIRP:

Bodemann reported that the draft ICNIRP ELF Guideline should be on their website in about 3 weeks and encouraged ICES to comment on draft. He also discussed a presentation that was prepared by Paolo Vecchia that addresses some of the ICNIRP activities (Attachment 5). He reported that the Task Group he chairs met in March in San Antonio (Kavet, Dovan, Chadwick, and Reilly).

7. Status of NATO/IEEE and IEEE Standard:

a) NATO Standardization Agency/IEEE Agreement:

Ziskin noted that the NATO Standardization Agency (NSA) and IEEE have entered into a Technical Cooperation Agreement to share knowledge of each organization's standards development activities to avoid duplication of technical standards whenever possible. A specific agreement for the development of a new IEEE civil standard to replace the NATO EMF standard adopted under STANAG 2345 is now being pursued. He said that the issue will be discussed further at the TC95/TC34 meeting on Sunday.

b) Issues on Merging C95.1 and C95.6:

Chou pointed out that one problem for ICES is how to adjust the rationale for effects related to neurostimulation. Murphy observed that WHO published a standards foundation document 5 years ago, which Anderson agreed to review. Murphy noted that the WB SAR can be exceeded in medical work and core temperature may not be best indicator. Chou quoted Michaelson and Frei's work and stated that in terms of standards activity, combining the two IEEE standards is a priority.

Two documents prepared by Dovan were discussed (Attachment 6 and Attachment 7). Both documents will be very useful in moving forward with the revision of C95.1 in that they raise a number of issues that have to be addressed. Included are detailed suggested revisions to the tables in C95.6 and possible conflicts that should be examined. Each item in the two attachments will be addressed by the editorial working group as the revision of the two standards (into a combined standard) moves forward.

c) Literature Surveillance

Morrissey discussed in detail the literature surveillance database and the literature evaluation process (Attachent 8). He noted that the IEEE database is located on the WHO website at Now on IEEE website at http://apps.who.int/peh-emf/research/database/IEEEdatabase/. He also discussed issues related to the different basic restrictions (BRs) and maximum permissible exposure (MPE) values for the different frequency ranges, and tissue-specific time-temperature thresholds. Murphy suggested that at some point the committee should consider another special issue of the BEMS Journal, similar to the 2003 issue that discussed much of the rationale of the then new standard.

8. **New Business:**

   Morrissey suggested addressing THz frequencies in the C95.1 revision. There are a number of studies being carried out at these frequencies by the Air Force that may be useful. D'Andrea suggested re-visiting the issue of a low-power device exclusions and de Seze pointed out how important to the public is the issue of risks associated with chronic exposure.

9. **Date and Place of Next Meeting:**

   Ziskin noted that the next meeting of TC95/SC3 and SC4 will take place in Washington DC sometime in December or January. After a brief presentation by Nam Kim, it was unanimously agreed that the summer 2010 meeting will take place in Seoul, South Korea in June in conjunction with the BEMS Annual Meeting.

10. **Adjourn 1540:**

    There being no further business, the meeting was adjourned at 1540 h.

Attendance – Joint TC95 SC3 and SC4 Meeting
Davos, Switzerland, 20 June 2009, 0900 – 1700 h

	Name (Last)	Name (First)	Affiliation	Membership Status	E-Mail
1.	Anderson	Vitas	ACRBR/Swinburn Univ	SC3/SC4	vitas@ieee.org
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5.	Chou	C-K	Motorola	SC3/SC4	ck.chou@motorola.com
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18.	Perentos	Nicholas	ACRBR/Swinburn Univ	O	n.perentos@gmail.com

	Name (Last)	Name (First)	Affiliation	Membership Status	E-Mail
19.	Pirunthavany	Muthuvelu	Min of Health-Malaysia	O	pirunthavany@moh.gov.my
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24.	Ziskin	Marv	Temple University	SC3/SC4	ziskin@temple.edu

O = Observer

ATTACHMENT 2

ICES

International Committee on Electromagnetic Safety

Unapproved Agenda

IEEE/ICES TC95 Subcommittee 3

(Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0 - 3 kHz)

and

IEEE/ICES TC95 Subcommittee 4

(Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz)

1.	Call to Order	*Chadwick & Ziskin*
2.	Introduction of those Present	*Chadwick & Ziskin*
3.	Approval of Agenda	*Chadwick & Ziskin*
4.	Approval of the Minutes (December 2008 Meeting)	
	a. Subcommittees 3 & 4	*Ziskin*
5.	Secretary's Report	*Petersen*
6.	Chairmen's Report	
	a. Subcommittees 3 & 4	*Ziskin*
7.	Status of NATO/IEEE STANAG	*Petersen*
8.	Issues on Merging of C95.1 and C95.6	*Chadwick & Ziskin*
	a. Rationale and Approach to Merging of the two Standards	
	b. Literature Surveillance	
	c. Literature Review/Evaluation	
	d. BRs and MPEs for Different Frequency Ranges	
	e. Terms and Definitions	
	f. Other	
9.	New Business	*Chadwick & Ziskin*
10.	Date and Place of Next Meeting	*Chadwick & Ziskin*
11.	Adjourn	*Chou*

ATTACHMENT 3

LEGISLATIVE SITUATION IN MALAYSIA

Pirunthavany Muthuvelu

Ministry of Health Malaysia (MOH)
Engineering Services Division

BACKGROUND

- There were public concerns over the health effects of base station with increasing mobile phone use since the 1990s.
- A NIR unit was set up in MOH to study the health effects in 1996

Standards

- The first Malaysian Standard, Part 1 for Controlling Exposure to Time Varying Electric, Magnetic and Electromagnetic Fields (Part 1: up to 3 kHz) is awaiting approval.

3 kHz to 300 GHz

- The draft document for Part 2 comprising 3 kHz to 300 GHz was completed by the technical committee and is awaiting public comments.

EXISTING ACTS

- In Malaysia, MCMC is the regulatory agency that governs the telecommunications industry via the Communications and Multimedia Act 1998 (Act 588).
- The energy industry is governed by the Energy Commission (EC) using the Electricity Supply Act 1990 and the Electrical Supply Regulations 1993

The Ministry of Housing and Local Government

- has endorsed two guidelines on the physical siting of mobile phone base stations or high power transmission lines.
- These are the Electricity Distribution Base Planning Standard and the Planning Guidelines on Telecommunication Transmission Structures and Base Stations.

At Present

- The Malaysian Government is adopting the precautionary approach to EMF exposure as recommended by the World Health Organisation (WHO) to manage any perceived health risks.
- Malaysia continues to adopt the International Commission on Non-Ionizing Radiation Protection (ICNIRP) standards for exposure limits.

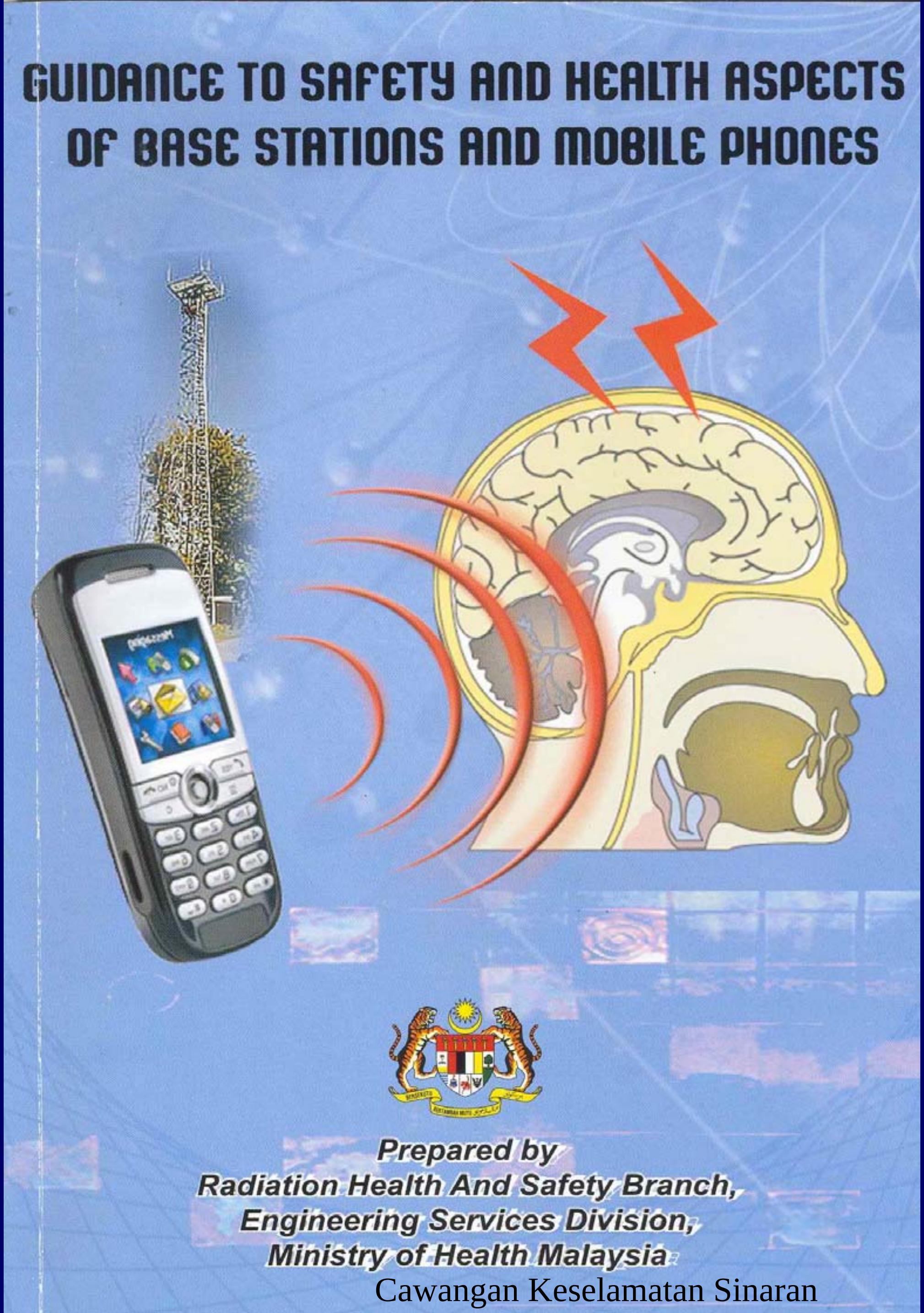
Precautionary Measures

- Restricting the construction and installation of mobile phone base station(s) in hospital and school compounds;

- Prohibiting the use of mobile phone(s) in the critical areas of hospitals;

Guidance Booklet

Guidance to Safety and Health Aspects of Base Stations and Mobile Phones


GUIDANCE TO SAFETY AND HEALTH ASPECTS
OF BASE STATIONS AND MOBILE PHONES
Prepared by
Radiation Health And Safety Branch,
Engineering Services Division,
Ministry of Health Malaysia

COMMITTEE

- Engineering Services Division, MOH - *Chairman*
- Malaysian Communication and Multimedia Commission (MCMC)
- Malaysian Nuclear Agency (Nuclear Malaysia)
- Ministry of Housing and Local Government (MHLG)
- Malaysian Technical Standards Forum Berhad (MTSFB)
- National Institute of Occupational Safety & Health (NIOSH)
- Standards Users, Standards Malaysia
- SIRIM Berhad
- Universiti Malaya (UM)
- Universiti Teknologi Malaysia (UTM)
- Universiti Tenaga Nasional (UNITEN)

Contents of this document

REFERENCES:

World Health Organization (WHO)
http://www.who.int/peh-emf/

Health Protection Agency - UK
http://www.hpa.org.uk/radiation/understand/radiation_topics/emf/index.htm

ICNIRP - International Commission on Non-Ionizing Radiation
http://www.icnirp.de/

Australian Radiation Protection and Nuclear Safety Agency
http://www.arpansa.gov.au/mobilephones/index.cfm

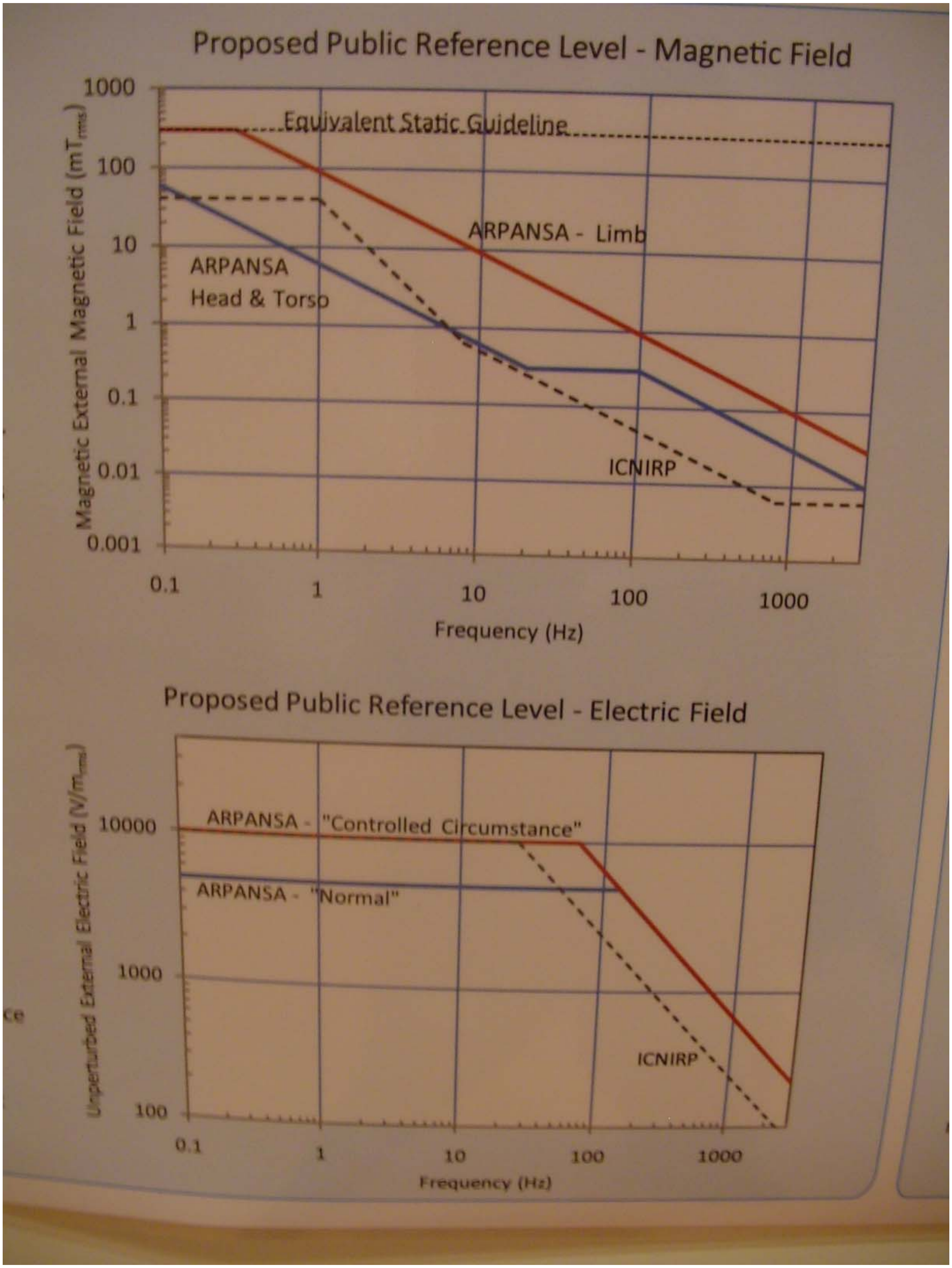
Other Concerns

- There is concern on the possibility of electromagnetic interference (EMI) to medical equipment in critical areas from the rapid development of telecommunication and wireless networking technology.
- The MOH in collaboration with the Malaysian Nuclear Agency is conducting site measurements in order to ensure the radiation level is below the recommended value

Conclusion

The prepared standards have to be reviewed again to keep pace with the latest ICNIRP revisions.

ATTACHMENT 4



ATTACHMENT 5

ACTIVITIES OF ICNIRP 2008-2009

Paolo Vecchia

Chairman of ICNIRP

DEVELOPMENT OF STANDARDS

Review of science ("Blue books")

↓

Evaluation of health risks (EHC Documents)

↓

Exposure guidelines

STATIC FIELDS

- **Guidelines published in 2009**

  Health Physics 96(4):504-514

  Translations available in Italian and Japanese

- **Fact Sheet posted on the website**

PROTECTION OF PATIENTS UNDERGOING MR EXAMINATIONS

Amendment to the Statement on Medical Magnetic Resonance (MR) Procedures: Protection of Patients

Introduction

ICNIRP published in 2004 a statement on the protection of patients undergoing medical magnetic resonance (MR) procedures (ICNIRP 2004). This statement was intended for use by international and national medical device regulatory authorities, MR users and health professionals, and those involved in the design and manufacture of MR equipment for clinical applications. Contraindications, precautions, and safety considerations for the patients were given. Recommendations on research with volunteers were also given.

Since publication of that statement, there have been further studies of the possible health effects of exposure to the high static magnetic field levels used in the new generation of MR systems (summarised by Noble et al, 2005 and AGNIR 2008) and in 2006 the World Health Organization (WHO) published a health risk assessment of static magnetic field exposure (WHO 2006). A revision concerning patient exposure to MR clinical procedures has been made by the UK Health Protection Agency (HPA, 2008). In addition, ICNIRP has recently published revised guidance on occupational and general public exposure to static magnetic fields (ICNIRP 2009). These revised guidelines recommended that occupational exposure of the head and trunk should not exceed a spatial peak magnetic flux density of 2 tesla (T) except for the following circumstance. For work applications for which exposures above 2 T are deemed necessary, exposure up to 8 T can be permitted if the environment is controlled and appropriate work practices are implemented to control movement-induced effects. Further guidance was issued regarding exposure of the general public.

In the light of this updated static magnetic field guidance and of the continuing development of MR technology and its important and wide-ranging applications in clinical diagnosis (Gowland, 2005), ICNIRP has decided to issue an amendment of the statement concerning patient exposure to static magnetic fields during these procedures. The advice concerning patient exposure to the switched gradient fields and RF fields recommended by ICNIRP (2004) remains current.

1

Amendment to the 1994 statement

Sent for publication

LOW-FREQUENCY FIELDS

Draft

ICNIRP Guidelines

GUIDELINES FOR LIMITING EXPOSURE TO TIME-VARYING ELECTRIC, AND MAGNETIC FIELDS

(1Hz TO 100 kHz)

International Commission on Non-Ionizing Radiation Protection

INTRODUCTION

In this document guidelines are established for the protection of people exposed to electric and magnetic fields in the extremely-low-frequency (ELF) range of the electromagnetic spectrum. For the purpose of this document the ELF range extends from 1 Hz up to 100 kHz. Guidelines for static field have been issued in a separate document (ICNIRP 2009). Those guidelines should be applied to movement induced electric fields or time varying magnetic fields up to 1 Hz. This publication replaces the ELF part of the 1998 guidelines (ICNIRP 1998).

These guidelines are based on scientifically established adverse biological effects resulting from exposure to (ELF) electric and magnetic fields. All biological effects of such exposure have been reviewed by IARC, ICNIRP, NRPB and WHO (IARC 2002, ICNIRP 2003, NRPB 2004, WHO 2007a). Those publications provided the scientific rationale for these guidelines.

DRAFT

These guidelines for limiting exposure have been developed following a thorough review of all published scientific literature. As detailed below, the basis for the guidelines is two-fold: Exposure to power-frequency electric fields causes well-defined biological responses, ranging from perception to annoyance, through surface electric-charge effects. In addition, the only well established effect in volunteers exposed to ELF magnetic fields are the stimulation of central and peripheral nervous tissues and the induction in the retina of phosphenes, a perception of faint flickering light in the periphery of the visual field. The retina is part of the CNS and is regarded as an appropriate, albeit conservative, model for induced electric field effects on CNS neuronal circuitry in general. In view of the uncertainty inherent in the scientific data, reduction factors have been applied in establishing the exposure guidelines.

SCOPE AND PURPOSE

The main objective of this publication is to establish guidelines for limiting EMF exposure that will provide protection against any established adverse health effects.

1

Coming soon…

Open for general consultation

www.icnirp.org

RF FIELDS

- **Review of science (Blue book)**

  Sections 1 (Physics/engineering) and 2 (Biology) to be posted on the website as pdf files

- **Review of epidemiology**

  Paper on mobile phones submitted for publication by SC IV

  Section 3 of the Blue book to be built-up

- **Interim confirmation of existing guidelines**

ATTACHMENT 6

SELECTED TEXT FROM C95.6 WITH COMMENTS IN BLUE

Thanh Dovan (May2009)

IEEE Std C95.6™-2002

IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0–3 kHz

2. References (to be updated ?)

This standard shall be used in conjunction with the following publications:[1]

Accredited Standards Committee C2-1997, National Electrical Safety Code® (NESC®).[2]

IEEE Std 644™-1994, IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines[3]

IEEE Std 1460™-1996, IEEE Guide for the Measurement of Quasi-Static Magnetic and Electric Fields.

3. Definitions, acronyms, and symbols

3.1 Definitions

For the purposes of this standard, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms,* Seventh Edition[B47], shall be referenced for terms not defined in this clause.

3.1.15 controlled environment: An area that is accessible to those who are aware of the potential for exposure as a concomitant of employment, to individuals cognizant of exposure and potential adverse effects, or where exposure is the incidental result of passage through areas posted with warnings, or where the environment is not accessible to the general public and those individuals having access are aware of the potential for adverse effects**. (Improvement/clarification to reflect both ELF & RF aspects ?)**

3.1.54 polarization (cellular): The electric potential formed across a cell membrane.

?polarization (linear, elliptical, circular:

3.1.60 rheobase: The minimum threshold intensity in a strength-duration relationship (applicable to a stimulus duration that is long in comparison with the strength-duration time constant). Also applied to the minimum plateau in a strength-frequency relationship.

?Right-Of-Way (ROW) or Easement (Power or Transmission Lines):

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[1] The IEEE standards referred to in Clause 2 are trademarks of the Institute of Electrical and Electronics Engineers, Inc.[3]The NESC is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

[2] IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, 08855-1331, USA (http://standards.ieee.org/).

[3] The NESC is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, 08855-1331, USA (http://standards.ieee.org/).

3.1.66 spark discharge: The transfer of current through an air gap requiring a voltage high enough to ionize the air, as opposed to direct contact with a source. **This is sometime referred to as a Micro-shock**

3.2 Acronyms and abbreviations

3.3 Symbols

4. Protected population and mechanisms of interaction (ELF+RF Context?)

5. Exposure limits

5.1 Basic restrictions

REPLACE TABLE 1 WITH 1A and 1b

Table 1—Basic restrictions applying to various regions of the body [a, b]

Exposed tissue	f_e (Hz)	General public	Controlled environment
		E_0 -rms (V/m)	E_0 -rms (V/m)
Brain	20	5.89×10^{-3}	1.77×10^{-2}
Heart	167	0.943	0.943
Hands, wrists, feet and ankles	3350	2.10	2.10
Other tissue	3350	0.701	2.10

Table 1a—Basic restrictions applying to various regions of the body [a, b]

Exposed tissue	f_e (Hz)	General public	Controlled environment
		E_0 -rms (mV/m)	E_0 -rms (mV/m)
Brain	20	5.89	17.70
Heart	167	943	943
Hands, wrists, feet and ankles	3350	2100	2100
Other tissue	3350	701	2100

[a] Interpretation of table is as follows: $E_i = E_0$ for $f \le f_e$; $E_i = E_0\,(f / f_e)$ for $f \ge f_e$.

[b] In addition to the listed restrictions, exposure of the head and torso to magnetic fields below 10 Hz shall be restricted to a peak value of 167 mT for the general public, and 500 mT in the controlled environment.

The Basic Restrictions (mV/m) of Table 1 varying with frequency are reproduced in Table 1b.

Table 1b—Basic restrictions at various frequencies [a, b]

Frequency range (Hz)	General public		Controlled environment	
	***E*-rms (mV/m)**	***Protected Tissue***	***E*-rms (mV/m)**	***Protected Tissue***
< 0.153	5.89	Brain	17.70	Brain
0.153–20	5.89	Brain	17.70	Brain
20–2380	0.2945 *f	Brain (f)	0.8850 *f	Brain (f)
2380 - 3000	701	Other tissue	2100	Other tissue

5.2 Maximum permissible exposure (MPE) values: Magnetic flux density

5.2.1 Exposure of the head and torso to sinusoidal fields

Table 2 lists maximum permissible magnetic field limits (flux density, *B*, and magnetic field strength, *H*) for exposure of the head and torso. The averaging time for an rms measure is 0.2 seconds for frequencies above 25 Hz. For lower frequencies, the averaging time is such that at least 5 cycles are included in the average, but with a maximum of 10 seconds.

OLD TABLE 2

Table 2—Magnetic maximum permissible exposure (MPE) levels: exposure of head and torso[a, b]

Frequency range (Hz)	General public		Controlled environment	
	***B*-rms (mT)**	***H* - rms (A/m)**	***B*-rms (mT)**	***H* - rms (A/m)**
< 0.153	118	9.39×10^4	353	2.81×10^5
0.153–20	$18.1/f$	$1.44 \times 10^4/f$	$54.3/f$	$4.32 \times 10^4/f$
20–759	0.904	719	2.71	2.16×10^3
759–3000	$687/f$	$5.47 \times 10^5/f$	$2060/f$	$1.64 \times 10^6/f$

[a] *f* is frequency in Hz. [b] MPEs refer to spatial maximum.

NEW TABLE 2

Table 2—Magnetic maximum permissible exposure (MPE) levels: exposure of head and torso[a, b]

Frequency range (Hz)	General public		Controlled environment	
	B -rms (uT)	*H* - rms (A/m)	*B* -rms (uT)	*H* - rms (A/m)
< 0.153	118 000	9.39×10^4	353 000	2.81×10^5
0.153–20	18 100/*f*	$1.44 \times 10^4/f$	54 300/*f*	$4.32 \times 10^4/f$
20–759	904	719	2 710	2.16×10^3
759–3000	687 000/*f*	$5.47 \times 10^5/f$	2060 000/*f*	$1.64 \times 10^6/f$

[a] *f* is frequency in Hz. [b] MPEs refer to spatial maximum.

5.2.2 Nonuniform exposure to sinusoidal magnetic fields

When the magnetic field is not constant in magnitude, direction, or relative phase over the head and torso, the maximum field over the head and torso shall be limited to the levels in Table 2. Alternatively, it shall be permitted to demonstrate adherence to the basic restrictions.

POLARIZED FIELDS ?

5.2.3 Exposure of the arms or legs

Maximum permissible exposure (MPE) levels for the arms or legs are listed in Table 3. Compliance with Table 3 ensures compliance with the basic limitations of Table 1. However, lack of compliance with Table 3 does not necessarily imply lack of compliance with the basic restrictions, but rather that it may be necessary to evaluate whether the basic restrictions are met.

ADD FREQUENCY RANGE TO TABLE 3

Table 3—Magnetic flux density maximum permissible exposure levels: exposure of arms or legs [a]

Frequency range (Hz)	General public *B* - rms (mT)	Controlled environment *B*- rms (mT)
< 10.7	353	353
10.7–3000	3790/*f*	3790/*f*

[a] *f* is frequency in Hz.

5.2.4 Pulsed or nonsinusoidal fields

5.3 Maximum permissible exposure values: environmental electric fields

5.3.1 Constant whole-body exposure to sinusoidal electric fields

Table 4 lists maximum electric field limits in terms of the undisturbed (absent a person) environmental field, *E*. It is assumed that the undisturbed field is constant in magnitude, direction, and relative phase over a spatial extent that would fit the human body. The averaging time for an rms measure shall be 0.2 seconds for frequencies above 25 Hz. For lower frequencies, the averaging time is such that at least 5 cycles are included, with a maximum of 10 seconds. For a controlled environment in which an exposed individual is not within reach of a grounded object, it may be acceptable to exceed the limits listed in Table 4. This standard does not specify limits for situations involving contact with ungrounded objects.

For purposes of demonstrating compliance with this standard, Table 2 and Table 4 shall be considered separately, and not additively. **This practical consideration takes into account differences exist in the characteristics of environmental electric and magnetic fields (single –field dominance, coupling to human body, phasing angle …) and the different requirement s for protection against indirect effects (power frequency electric field) and electrostimulation (ELF magnetic fields).**

Table 4—Environmental electric field MPEs, whole body exposure

General public		Controlled environment	
Frequency range (Hz)	***E* - rms (V/m)**	**Frequency range (Hz)**	***E* - rms (V/m)**
1–368[c]	5000[a,d]	1–272[c]	20 000 [b,e]
368–3000	$1.84 \times 10^6/f$	272–3000	$5.44 \times 10^6/f$
3000	614	3000	1813

NEW TABLE 4

Table 4—Environmental electric field MPEs, whole body exposure

	General public	Controlled environment
Frequency range (Hz)	***E* - rms (V/m)**	***E* - rms (V/m)**
1–272[c]	5000[a,d]	20 000 [b,e]
272–368[c]	5000[a,d]	$5.44 \times 10^6/f$
368–3000	$1.84 \times 10^6/f$	$5.44 \times 10^6/f$
3000	614	1813

[a]Within power line rights-of-way, the MPE for the general public is 10 kV/m under normal load conditions.
[b]Painful discharges are readily encountered at 20 kV/m and are possible at 5–10 kV/m without protective measures.
[c]Limits below 1 Hz are not less than those specified at 1 Hz.
[d]At 5 kV/m induced spark discharges will be painful to approximately 7% of adults (well-insulated individual touching ground).
[e]The limit of 20 000 V/m may be exceeded in the controlled environment when a worker is not within reach of a grounded conducting object. A specific limit is not provided in this standard.

5.4 Contact and induced current maximum permissible exposure limits

5.4.1 Sinusoidal current

Table 5— Induced and contact current MPEs (mA-rms) for continuous sinusoidal waveforms, 0–3 kHz[a, b]

Frequency Range (Hz)	Condition	General public (mA, rms)	Controlled environment (mA, rms)
0 – 3000	Both feet	2.70	6.0
	Each foot	1.35	3.0
	Contact, grasp	—	3.0
	Contact, touch	0.50	1.5

[a]Grasping contact limit pertains to controlled environments where personnel are trained to effect grasping contact and to avoid touch contacts with conductive objects that present the possibility of painful contact.
[b]Limits apply to current flowing between body and grounded object that may be contacted by the person.

5.4.2 Nonsinusoidal (pulsed or mixed frequency) current

6. Rationale

6.1 Excitation thresholds: strength-duration and strength-frequency laws

Table 6—Models for established thresholds of reaction: median *in situ* E-field thresholds[a, b]

Reaction	E_o pk (V/m)[c]	τ_e (ms)	f_e (Hz)
Synapse activity alteration, brain	0.07	525.0	20
10-µm nerve excitation, brain	12.3	0.149	3350
20-µm nerve excitation, body	6.1	50.149	3350
Cardiac excitation	12.0	3.00	167

[a]Interpretation of table as follows: $E_i = E_0$ for $t_p \geq \tau_e$; $E_i = E_0(\tau_e/t_p)$ for $t_p \leq \tau_e$. Also, $E_i = E_0$ for $f \leq f_e$; $E_i = E_0(f/f_e)$ for $f \geq f_e$.
[b]Adapted from Reilly [B75].
[c](*V/m-pk*) refers to the temporal peak of the electric field.

6.1.1 Nerve excitation

Excitation of nerve and muscle requires depolarization of the membrane resting potential by about 15–20 mV—the exact amount depends upon the stimulus waveshape and other factors. In the region of a locally constant electric field, excitation is initiated where a nerve is terminated, or undergoes a rapid bend, such as may occur at a motor neuron end plate or at sensory receptors (Reilly [B71], [B75]). Under these conditions the threshold of excitation is inversely proportional to the diameter of the nerve axon.

…

To determine basic restrictions, it is conservative to assume a small value of τ_e, rather than a large one. Consequently, Table 6 adopts a value of τ= 149 µs as suggested by an average of the lower experimental *e* values mentioned above. The theoretical value of E_o =6.15 V/m is considered a median within a distribution of thresholds in healthy adults. Although adequate statistical data is lacking, sufficient data on E_o is available to suggest that the assumption is reasonable. Where the induced E-field could be determined, rheobase for pulsed magnetic stimulation of the forearm was found to be 5.9 V/m (Havel et al. [B39]). In addition, an underlying neural excitation assumption of 6.15 V/m correctly reproduces the distribution of let-go current thresholds in adults (Sweeney [B94]). Furthermore, thresholds of excitation with pulsed magnetic stimulation calculated with E_o = 6.15 V/m are reasonably consistent with experimentally determined thresholds (6.3).

To be prepared and added [e.g. In a recent publication (Wood, 2008) have presented a range of excitation thresholds and concluded that taking into account … a threshold of 2V/m has been used in the development of the Australian ARPNSA ELF Standard.]

The most sensitive means of exciting skeletal muscle is via electrostimulation of the motor neurons that innervate it. Consequently, thresholds for muscle stimulation follow those for nerve excitation. An exception to this occurs with cardiac stimulation, as described below.

6.1.2 Cardiac excitation

6.1.3 Synaptic activity alteration

Using data from magnetophosphenes (Lövsund et al. [B57], [B58]) the corresponding induced E-field in thehead at the most sensitive frequency tested (20 Hz) is 0.079 V/m-rms as calculated with an ellipsoidal model of the head (see Annex B). At the retina, where the electrical interaction is thought to take place, the calculated field is 0.053 V/m-rms, which is consistent with the current density threshold of 0.008 A/m^2 at the retina determined for electro-phosphenes (Lövsund et al. [B58]) assuming the conductivity of the brain is 0.15 S/m. The internal E-field corresponding to phosphene perception at the optimum frequency is a factor of 100 or so below rheobase thresholds for neural stimulation.

To be prepared and added [e.g. In a recent publication (Wood, 2008) have presented a range of synaptic effect thresholds on and concluded that taking into account … a threshold range of 10 to 100 mV/m has been reported and a BR of 10mV/m have been used in the development of the Australian ARPNSA ELF Standard.]

Experimental strength-duration data show that τ^e for phosphenes using electrodes on the temples is approximately 14 ms (Baumgart [B7]; Bergeron et al. [B10]) and for electrically evoked potentials in the frog's eye, is in the range 14–36 (Knighton [B53], [B54]). These values are consistent with the phosphene data described above, but are about 100 times greater than corresponding values for peripheral nerves.

Relatively few data exist on synaptic polarization effects by applied electric fields. Considering this dearth of data, reasonable assumptions are made based on the available synaptic effects experimental data and on assumed parallels with nerve excitation properties. One class of these properties concerns strength-duration and strength-frequency characteristics. An average strength-duration time constant for synapse effects is =25 ms. Using the relationships noted for nerve excitation, a strength-frequency constant of f_e = 20 Hz is expected above which *in situ* electric field thresholds should rise. This rise is indeed observed in the case of electrophosphene thresholds, although the rate of rise is greater than that observed with nerve excitation (Adrian [B2]; Clausen [B24]). Magneto-phosphene strength-frequency curves reported by Lövsund and colleagues ([B57], [B58]) show a minimum at 20 Hz, and rising thresholds at lower frequencies, in accord with electrophosphene data. Thresholds above 20 Hz vary somewhat with the experimental parameters (background illumination and wavelength, subject visual acuity). Considering electro- and magneto-phosphene strength-frequency and strength-duration curves in total, it is reasonable to adopt a threshold curve similar to that found in electrostimulation of nerve and muscle, but with a much lower strength-frequency constant (or equivalently, a larger strength-duration time constant), and with lower rheobase. Additional study of CNS synaptic interaction effects is needed to clarify these assumptions.

Frequency sensitive thresholds for phosphenes have been experimentally tested only to a maximum frequency of about 75 Hz. The Subcommittee makes the conservative assumption that synaptic polarization thresholds follow a frequency-proportional law above 20 Hz to a frequency of at least 760 Hz (above which peripheral nerve excitation limits dominate the magnetic field MPEs).

In connection with phosphene threshold experiments, Lövsund and colleagues ([B57], p. 330) state: "Virtually all the volunteers noted tiredness and some reported headaches after the experiment. Some experienced afterimages which were generally of only short duration following exposure to the magnetic field. In one case, however, they persisted up to ten minutes after the experiment. Individual volunteers reported spasms of the eye muscles, probably arising from stimulation by the field." These findings were similar to those of Silny [B92], who reported headaches, indisposition, and persistent visual evoked potential (VEP) alterations at flux density levels above phosphene thresholds, but still well below nerve excitation thresholds (by a factor of 23).

Clearly adverse reactions that may be attributable to CNS reactions (tiredness, headaches, muscle spasms, persistent afterimages) are reported in connection with phosphene threshold experiments. It is unlikely that the phosphenes themselves were causing the reported adverse reactions. A plausible explanation is that the adverse effects were due to electrostimulation of brain neurons in accord with the synapse mechanism discussed previously.

The ability of sub-excitation fields to alter neuronal response has also been reported after exposure of hippocampal slices from the rat brain to magnetic fields (Bawin et al., [B8, B9]) in which induced E-field intensities were as low as 0.75 V/m peak—a factor of 16 below the threshold of 12.3 V/m for excitation of a 10-µm neuron. The rate of maze learning in living mice was significantly reduced by exposure to flux densities at and below 0.75 mT at 50 Hz (Sienkiewicz et al. [B90], [B91]). Although the cited studies did not establish a synaptic mechanism, they do support the view that CNS effects, including adverse ones, are possible well below thresholds of excitation of brain neurons.

The spinal cord also contains synapses, **however they are not the more sensitive ribbon-type of the retina, cochlea, pineal gland and vestibular organs**. Spinal functions are important to the organism (e.g., control of posture; reflex activity). Tests have been conducted with human subjects whose torsos were subjected to the strong switched gradient fields of experimental MRI systems (see 6.1.1 and 6.3.2). Perception was sometimes preferentially reported in the small of the back at stimulus levels corresponding to nerve stimulation thresholds in accord with expectations from an elliptical induction model (see 6.3.2 and Annex B). These tests showed no observable effects below the neural threshold for perception. The lack of an observable effect below electrical perception thresholds suggests one of three possible explanations. One is that spinal synapse interactions did occur, but they were imperceptible to the subject. Another is that the induced field in the spinal column was below synapse interaction thresholds, even though the levels just outside of the spinal column were roughly two orders of magnitude above synapse thresholds. A third is that stimulation thresholds are significantly greater than what has been assumed for synaptic effects in brain neurons (Table 6).

Considering that the Subcommittee could find no data to suggest observable effects from stimulation of the spinal cord at the levels attributed to synapse thresholds, protection in this standard is focused on the brain, rather than the spinal cord.

6.1.4 Averaging time

6.1.5 Spatial averaging

6.2 Adverse reaction criteria

6.3 Threshold limits for magnetic field exposure

To derive an environmental magnetic field from allowable *in situ* E-field magnitudes, it is necessary to apply an induction model. Traditional methods used to predict whole body energy absorption during magnetic field exposure include the use of ellipsoid shapes arranged to mimic an animal or man (Reilly [B72]). During the past several years, high-resolution anatomical models have been developed to enhance the capability to predict localized energy absorption, such as within a single organ or part of an organ.

6.3.1 Detailed anatomical induction models (update section?)

The development of the high-resolution models has enhanced tremendously the understanding of energy absorption during electromagnetic field exposure. However, this development has also revealed several inadequacies in present knowledge regarding dosimetry. Hurt and colleagues [B41] demonstrated how variability in published permittivity values influence specific absorption rate (SAR) calculations. Although SAR values are pertinent only at the higher frequencies, the influence of permittivity values on predicted induced internal fields produced by the lower exposure frequencies should also be determined. Mason and associates [B60] evaluated the influence of voxel size on the predicted energy absorption during electromagnetic field exposure. Increasing voxel size could either increase or decrease the predicted amount of energy absorbed within a voxel. In general, there was usually a decrease in the amount of energy absorbed, but this was not always the rule. It appears that the better solution is to use the highest-resolution model available, and then average the amount of energy absorbed amongst the voxels. However, even if a model has a small voxel size, this does not necessarily imply that the high-resolution anatomy or separation of anatomical components has been adequately incorporated.

A comparison of induced electric field calculations obtained by several investigators using a similarly detailed anatomical model and similar numerical techniques (Dawson and Stuchly [B28]; Dimblylow [B30]; Gandhi [B37]) showed differences of over 5:1 in the maximum field in critical organs; organ averages were usually reasonably consistent, although differences as great as 2:1 were noted. Since the basic restrictions of this standard depend on the maximum field in particular organs, large variations in reported maximum values make it difficult to apply presently available detailed models to standards.

An important missing element in high resolution modeling is validation. Simply producing a model is insufficient for declaring that the results produced by using this model are accurate. Substantial laboratory testing on biological tissue should be incorporated into any model development. Comparison of the theoretical and empirical results and the subsequent refining of a model are essential in order to earn the credibility essential when using these models to establish or revise exposure standards.

6.3.2 Ellipsoidal induction model

ADD SUPLEMENT TABLE SHOWING FREQUENCY RANGE

Table 7—Models for established magnetic dB/dt thresholds of reaction: whole body exposure; median thresholds[a]

Reaction	- pk (T/s)b $\dot{B}_o$	τ_e (ms)	f_e (Hz)
Synapse activity alteration, brain	1.4	5 25.0	20
10-µm nerve excitation, brain	237	0.149	3350
20-µm nerve excitation, body	37.	50.149	3350
Cardiac excitation	88.7	3.00	167

[a]Interpretation of table as follows: $\dot{B} = \dot{B}_o$ for $t_p \geq \tau_e$; $\dot{B} = \dot{B}_o(\tau/t_p)$ for $t_p \leq \tau_e$.
Also, $\dot{B} = \dot{B}_o$ for $f \leq f_e$; $\dot{B} = \dot{B}_o(f/f_e)$ for $f \geq f_e$.

[b](*T/s-pk*) refers to the temporal peak of the magnetic flux density.

ADD SUPLEMENT TABLE SHOWING FREQUENCY RANGE

Table 8—Median magnetic flux density thresholds; whole body exposure[a]

Reaction	B_0 - rms (mT)	H_0 - rms (A/m)	f_e (Hz)
Synapse activity alteration, brain	8.14	6.48 × 10³	20
10-µm nerve excitation, brain	7.97	6.34 × 10³	3350
20-µm nerve excitation, body	1.27	1.00 × 10³	3350
Cardiac excitation	59.8	4.76 × 10⁴	167

[a]Interpretation of table as follows: $B = B_o$ for $f \geq f_e$; $B = B_o(f_e/f)$ for $f \leq f_e$.

Considering the procedures discussed above, it is apparent that the flux density limits in Table 8 are based on the assumed *in situ* limits of Table 6 evaluated at the site of interaction. For instance, the brain exposure limits are based on the estimated field induced in the outer perimeter of the cerebral cortex; cardiac excitation applies to the field induced in the apex of the heart; and peripheral nerve limits are based on the maximum induced field in the periphery of the torso.

6.4 Static or quasi-static magnetic field exposure

6.5 Nonsinusoidal or pulsed fields

6.6 Exposure to environmental electric fields

Since environmental electric fields induce *in situ* electric fields and body currents, it might seem logical to conclude that the induced field should be limited by **the Basic restrictions** so as to preclude direct electrostimulation effects. In practice, however, contact current and spark discharge criteria (indirect electrostimulation) limit environmental electric fields to values significantly lower than what is required to directly induce *in situ* electric fields at the levels in Table 1 and Table 6. For example, the basic restriction for the *in situ* electric field in the brain is 17.7 mV/m at 60 Hz for the general public (Table 1). To induce this field of 17.7 mV/m in a grounded, erect person would require an environmental field of about 59 kV/m (Carstensen [B22] **(e.g about 0.3 mV/m per 1kV/m of environmental electric field).**

Considering that the undisturbed field is enhanced at body surfaces—18 times, for example, on the head of an erect person (Kaune [B51]), and even greater enhancements are possible on extended fingertips—parts of the body could be in a state of corona at environmental field levels necessary to induce the cited E-field **Basic Restriction** within the brain.

Indirect stimulation effects occur through charge transfer between a person and a conducting object within the field. With sufficiently strong fields, an individual can perceive spark discharges just prior to the moment of direct contact and just after breaking contact with conducting objects that are well insulated from ground. It is also possible to perceive current through direct contact with such objects.

The contact current component, I_c, for an erect person touching a grounded conductor in a vertically polarized electric field is shown in Equation (10) (Reilly [B75])

$$I_C = 9.0 \times 10^{-11} - h^2 fE \qquad (10)$$

where

h is the height of the person
f is the frequency of the field
E is the environmental field strength

For fields with frequencies within the limits of this standard, in which the environmental field magnitude varies over the area that would be occupied by the body, the field strength in Equation (10) may be replaced with the average environmental field over the area in which the body is placed (Deno and Zaffanella [B29]; Kaune [B51]).

Exposure limits on environmental electric fields in Table 4 are intended to avoid aversive or painful contact currents or spark discharges when an erect person touches a conductive path to ground. In this instance, the individual is the induction object if that person is insulated from ground (rubber sole shoes, standing on an insulated surface, etc.). The limits may not protect grounded individuals from adverse electrostimulation when touching large conductive objects that are insulated from ground.

The field limitations in Table 4 that provide protection against adverse contact current vary in inverse proportion to frequency. If this law were to extended to zero frequency, the electric field limit would approach infinity. An upper limit is placed on the maximum permissible E-field to limit the probability of an adverse reaction to a spark discharge.

The maximum permissible field in Table 4 is 5 kV/m for the general public. It is estimated that spark discharges would be painful to approximately 7% of adults who are well insulated and who touch a grounded object within a 5 kV/m (50/60Hz) field. Unpleasant spark discharges **and contact currents** can also occur when a grounded person touches a large conductive object that is well-insulated from ground situated within a strong field. It is not possible to absolutely protect against all possibility of adverse stimulation without mitigating the induced charge on the object when very large (or long) objects are situated near sources that produce electric fields that are very extended spatially, such as is the case with high-voltage power transmission lines. For instance, one might postulate a long fence wire on insulated posts running parallel to a high-voltage transmission line. In such cases, it is preferable to restrict electrostimulation & contact currents by properly grounding the conducting object (as stated in other safety codes), rather than by limiting the electric field to an impractically small level.

In the controlled environment where the MPE is limited to 20 kV/m, painful spark discharges, but not contact currents, can be readily encountered at the stated limit for an insulated person at ground level touching a grounded conductive object. In such strong fields, workers should limit the probability of painful spark discharges by appropriate use of protective clothing, grounding measures, contacting techniques, or other work practices that consider these environmental electric field effects. In the controlled environment, conductive suits can be worn that shield the body from high environmental electric fields, thereby greatly reducing indirect electrostimulation. Currents conducted to the body of individuals wearing protective clothing shall not exceed those in Table 5.

OLD TEXT

Power line rights-of-way fall somewhere between the definitions of "controlled" and "uncontrolled" environments for the general public in that public activity can be circumscribed by the utility, but that public access is often allowed for the public benefit. Consequently, this standard specifies a limit of 5 kV/m for the general public in regions off the right-of-way, but allows an intermediate field of 10 kV/m within the right-of-way under normal load conditions. (If the powerline right-of-way conforms to the requirements of a controlled environment, then the controlled environment limits apply.) Experimental data using spark discharge stimuli on human subjects (Reilly [B75]; Reilly and Larkin [B81]) can be applied to this exposure. In a field of 10 kV/m, about 50% of adult subjects (1.8 m tall) who are well insulated from ground would experience painful discharges when contacting a grounded conductor. The stated probability would increase with taller subjects and decrease with shorter ones. It is also decreased by imperfect insulation of the person with respect to ground.

NEW TEXT (to include easements and to be improved further?)

Power line rights-of-way or Easements have some feature of the "controlled" environment because public activity and land-use can be regulated/circumscribed by the utility, but that public access and limited land-use is often allowed for the public benefit. For electrical safety, electric transmission utilities also have public information and engineering measures for mitigation of indirect effects discussed above. Consequently, this standard specifies a limit of 5 kV/m for the general public in regions off the right-of-way, but allows an intermediate field of 10 kV/m within the right-of-way under normal load conditions. (If the powerline right-of-way conforms to the requirements of a controlled environment, then the controlled environment limits apply.) Experimental data using spark discharge stimuli on human subjects (Reilly [B75]; Reilly and Larkin [B81]) can be applied to this exposure. In a field of 10 kV/m, about 50% of adult subjects (1.8 m tall) who are well insulated from ground would experience painful discharges when contacting a grounded conductor. The stated probability would increase with taller subjects and decrease with shorter ones. It is also decreased by imperfect insulation of the person with respect to ground.

Maximum electric fields permitted within and off power transmission line rights-of-way are subject to limitation from other agencies or requirements, such as the U.S. National Electrical Safety Code and other electric utility regulations. The National Electrical Safety Code® (NESC®) (Accredited Standards Committee C2-1997) specifies a safety limit of 5 mA short circuit current (i.e., the current into a low-impedance connection to earth) from objects within the electric field of a high-voltage transmission line. The intent of this provision is to limit contact currents to the "let-go" level of a few percent of sensitive children under worst case conditions, rather than to avoid aversive or painful perception of contact current or spark discharges.

In the absence of indirect stimulation, environmental E-fields can sometimes be perceived through vibration of body hair caused by the interaction of the field and charged hair follicles. With a sufficiently strong field the sensation can be annoying to some people. For instance, at 20 kV/m in an outdoor environment, 50% of standing adults can perceive a 60 Hz field, and about 5% will consider the sensation annoying (Deno and Zaffanella [B29]; Reilly [B69]). Although 20% of subjects perceived a 60-Hz electric field at 9 kV/m, less than 5% could detect electric fields of 2 or 3 kV/m (Reilly [B69]). With hands raised above the body, the median perception threshold is 7 kV/m.

When an exposed individual is not within reach of a grounded conducting object, such as with a live power line worker in an insulated bucket, the maximum exposure limits in Table 4 may not apply. In such cases, the magnitude of contact current and spark discharges will be determined by the potential difference between the individual and the touched object, and their capacitances. The Subcommittee recommends adherence to the limits of Table 4 for the general public, however, the limits of Table 4 may be exceeded in controlled environments in which workers are not within reach of grounded conducting objects. The Subcommittee does not have a specific recommendation at this time for this situation. Regardless of the size and proximity of conducting objects that may be touched by the exposed individual, an absolute upper limit on acceptable exposure will be determined by the need to prevent corona on body surfaces. It is unlikely that exposures in excess of 30 kV/m (undisturbed field) would be acceptable on any exposed body part.

6.7 Static or quasi-static electric fields

6.8 Statistical variations in thresholds of reaction

6.9 Acceptance criteria

6.9.1 Basic restrictions

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Table 10—Factors for converting median thresholds to MPE values

A	B	C	D	E	F Safety factor (F_s)		G Basic restrictions (E_{ob})	
Reaction	**Locus**	**Threshold E_{ot} (50%) (V/m, rms)**	**Adverse mult. (F_a)**	**Prob. mult. (F_p)**	**General public**	**Contr. environ**	**General public (V/m, rms)**	**Contr. environ. (V/m, rms)**
Synapse alter.	Brain	0.053	1.0	0.333	0.333	1.000	5.89×10^{-3}	1.77×10^{-2}
10-µm neuron excite	Brain	8.70	1.0	0.333	0.333	1.000	0.970	2.90
20-µm neuron pain	Body	4.35 (percept.)	1.45 (pain)	0.333	0.333	1.000	0.700	2.10
20-µm neuron pain	Hands, feet, wrists, ankles	4.35 (percept.)	1.45 (pain)	0.333	1.000	1.000	2.10	2.10
Cardiac excite	Heart apex	8.49	1.0	0.333	0.333	0.333	0.943	0.943

EXPLAIN HOW THE THRESHOLDS REFLECT BACK TO TABLE 1

6.9.1.1 Adverse reaction factor

6.9.1.2 Probability factor

6.9.1.3 Safety factor

A safety factor multiplier of F_s = 0.333 allows for protection of exceptionally sensitive individuals, uncertainties concerning threshold effects due to pathological conditions or drug treatment, uncertainties in the reaction thresholds, and uncertainties in the induction models. In the case of the hands, wrists, feet, and ankles, F_s =1 for the general public in recognition of the narrow cross sections and preponderance of low conductivity tissue that tend to enhance the *in situ* E-field in these areas in comparison with other areas of the body. Because these regions lack critical function when compared with the vital organs, a greater localized electric field is permitted. In the case of the controlled environment, F_s = 1 for all of the reaction types except for cardiac excitation under the assumption that a small probability of discomfort is acceptable in the controlled environment for some mechanisms, but that cardiac excitation is unacceptable for all individuals. The safety factor F_s = 1 can be justified for the indicated exposures because this standard is based on avoidance of short-term reactions that are immediately apparent to the exposed individual, rather than chronic exposure health effects at sub-perception levels, and where cumulative exposure might be significant. It is assumed that, because the short-term reactions are apparent to exposed individuals, they can remove themselves from the environment, modify their activities, or can take other action to avoid the exposure entirely.

If the safety factor F_s =0.333 is to be compared with that applied at higher frequencies of IEEE Std C95.1, note that a divisor of 3applied to the magnitude of the induced field is equivalent to a divisor of 9 in the SAR because SAR is proportional to the square of the induced field.

To be prepared and added [Refer to ICNIRP and ARPANSA approaches…In other standard guidelines a factor of]

Factor to account for experimental data variation/uncertainty in the determination of threshold for standard from data threshold ?

6.9.2 Maximum permissible exposure levels

6.10 Partial or nonuniform exposure (discuss field polarisation?)

6.11 Induced and contact current

6.11.1 General relationships

6.11.2 Illustration of statistical relationships

6.12 Medical devices and metallic implants (Update?)

Annex A

(informative)

Bibliography (UPDATE?)

Where papers from scientific conferences or technical reports are cited, it is because such information is not otherwise available in refereed sources.

[B1] AAMI, "Active implantable medical devices—Electromagnetic compatibility—EMC test protocols for implantable cardiac pacemakers and implantable cadioverter defibrillators (draft)," Report AAMI PC69, American Association of Medical Implants, Arlington VA, USA, 2000.

Annex B

(normative)

Magnetic induction model

Table B.1—Elliptical exposure model used to compute magnetic induction[a, b]

Item	Exposure	*b, a* (cm, cm)	*u, v* (cm, cm)	E_o (V/m-pk)	(T/s-pk) $\dot{B}_o$
1	10-µm nerve, brain, sagittal	9, 10.5	9, 0	12.3	237
2	Synapse, brain, sagittal	9, 10.	59, 0	0.07	51.45
3	20-µm nerve, body, sagittal	17, 90	17, 0		
4	20-µm nerve, torso, coronal	20, 40	20, 0	6.1	538.4
5	Heart, body, sagittal	17, 90	14, 18	12.0	88.7
6	Heart, torso, sagittal	17, 40	14, 18	**9.0**	98.6
7	Leg	9, 42	9, 0	6.1537.5	6.1571.5