Approved Meeting Minutes
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

13:00 – 15:00 h GMT
Wednesday, 03 June 2020 & Thursday, 04 June 2020
Electronic Meeting by WebEx

1. Call to Order
   The meeting was called to order by the co-chair of SC3, Alexandre Legros at 13:00 h GMT

2. Welcome Participants
   The participants were welcomed and administrative details for this WebEx meeting were given.
   (See Attachment 1 for list of attendees.)

3. Approval of Agenda
   The proposed agenda was presented. Marv Ziskin suggested an additional agenda item on the vote on Corrigendum 2 of C95.3. This was added to the agenda.
   Following a motion by Ziskin that was seconded by Kavet, the agenda was unanimously approved. (See Attachment 2.)

4. Approval of the Minutes (22 January 2020 Meeting)
   The Minutes of the meeting held on 22 January 2020 in Plantation (FL) were discussed. There were no additional comments.
   C-K Chou moved to approve the January 2020 SC3/SC4 minutes. The motion was seconded by Marv Ziskin. The motion passed unanimously. (See Attachment 3).

5. Call for Patents
   SC3 Co-chair Legros made a “call for patents” relating to the work performed by members of SC3 and SC4 in making standards. (See bottom of the agenda). The chairman asked the SC’s if there were any such patents assigned to SC members; there was none.

6. Chairmen's Reports
   SC3/SC4 Co-chairs
   - Ziskin announced the new co-chair of SC3/4 being Alexandre Legros, he is the successor of Kevin Graf who moved to the FCC. The other co-chair of SC3 remains Rob Kavet.
   - For SC4 the co-chair is Art Thansandote.
   - Major SC3/4 tasks were reviewed, the most important of which was the approval of corrigendum No 1 by IEEE and the insertion of the comments.
Following the approval of C95.1-2019, advertisement was performed by means of announcement to Major Regulatory Bodies, International Web Sites and a publication in IEEE Access with a synopsis of the new standard. This synopsis has undergone a revision.

Ongoing work on the ICES Data Base and Literature Review was carried out by Joe Elder and Antonio Faraone.

Pat Roder from IEEE staff received a special thanks because of her invaluable work to make progress on the IEEE side of the standardization process.

A letter was produced by ICES to FCC regarding a response on the release of FCC Proposed Rule Making on Exposure Limits being “Resolution of Notice of Inquiry, Second Report and Order, Notice of Proposed Rule Making, and Memorandum Opinion and Order”. The next step to be taken is IEEE legal approval followed by submission to the FCC. The letter can be found in the chairman’s report. (Attachment 4)

A second Corrigendum on C95.1-2019 was produced. The corrigendum 2 was a result of the discovery of errors in Figures 1 and 2 of C95.1-2019. A schedule to resolve the errors and to finally publish the Corrigendum 2 by IEEE was presented.


- Update on the revision of ICNIRP guidelines on HF fields
  
  Aki Hirata briefed the latest information on the revision on ICNIRP RF guidelines. SC 3 members were thanked for their valuable input and comment on the guideline. After publication of the new RF guideline this was addressed in a special issue of Health Physics 118. The ICNIRP workplan 2020-2024 was presented. Tentative this will include:
  1. LF guidelines.
  2. Static Magnetic field.
  3. Laser guidelines.

Furthermore, necessity for addressing local ERL in LF was considered. Antonio Faraone asked whether ICNIRP and WHO share a research agenda. Aki Hirata answered that this is not the case. The research agenda of ICNIRP is focused on the ICNIRP guideline and not on the WHO research agenda.

- ELF/RF literature surveillance
  
  Since early 2020 no contract support of Mobile and Wireless Forum in keeping the literature database. So very few papers have entered the database since then. Joe Elder brought up that copyright issues brought up by IEEE might be the underlying cause for that. Pat Roder mentioned that there had been discussions between the ICES –chair (Jafar Keshvari) and the IEEE IP staff about the database and its maintenance. Jafar Keshvari was about to address the IEEE recommendations at the next Adcom meeting.

  2. A paper on “Genetic susceptibility may modify the association between cell phone use and thyroid cancer. A population-based case-control study in Connecticut” was brought to the attention of the group. The paper is in the database under number 7460.

- Report on the C95.1-2345-2014 revision
  
  Since Roel Escobar did not attend the meeting there was no report. Report will be given on TC-95 meeting on June 19th.
d) Because there was some time left for the meeting, several standards related topics were discussed.

1. A discussion on how to deal with future changes, keeping in mind the IEEE change process. Several options were brought up, either collect all change proposals for the next revision or issue separate corrigenda.

2. How to keep track of change proposals and how to communicate about them in the group. It was suggested that the ICES website could be the place for that. Possibly with a Wiki like format.

3. Access to the standards through the IEEE GET program is not easy. People have different experiences with that. It should be more straightforward.

4. Alexandre Legros mentioned that he is also involved in IRPA (International Radiation Protection Association) and that they want to focus more on NIR. They are concerned about the alleged 5G-COVID 19 connection and want to bring out a statement on that. Possible support from SC3 and 4 was asked, but C-K Chou replied that SC3 and SC4 are about standards. Rick Tell brought up that COMAR has issued a Technical Information Statement on 5G that may be of help, although the TIS does not mention COVID 19. The TIS will be published in Health Physics 119, August edition.

8. Vote on Corrigendum 2

The proposed corrigendum was presented by Marv Ziskin. See Attachment 6. The actual vote was not done at the meeting because the names of voters and contributors to the document have to be incorporated in it. Instead of that, an approval of the modified figures in the corrigendum was asked from the group. The acceptance of the change was approved unanimously by the subcommittee meeting. To approve the corrigendum, an email-in vote will be held within a week. The necessary information for this will be collected by Peter Zollman.

9. Technical Presentations

a) Non-invasive brain stimulation; relevance to standards

Marom Bikson presented his view on non-invasive brain stimulation. Several brain stimulation techniques were highlighted. Furthermore, safety in Neuroromodulation was addressed focusing on the tradeoff between benefit, the risk of injury and what can be tolerated during treatment. The talk concluded with slides about how Neuroromodulation changes brain function. The presentation can be found in Attachment 7.

b) A tutorial on a description of ICNIRP’s new RF guideline with a comparison to ours

C-K Chou presented a summary of the EMF exposure standards. He focused on the differences between ICNIRP and IEEE, as well from an organizational point of view as from the standards being produced. See Attachment 8.

Ric Tell highlighted the differences between the standards below 6 GHz. He called for more harmonization efforts to split the differences between the harmonization bodies. See Attachment 9.

Ken Foster concluded with his presentation on comparison of C95.1-2019 with ICNIRP (2020 in the 6-300 GHz region. In general there are not many differences between the two standards in that area. See Attachment 10.
A summary of the FCC’s NPRM and associated issues (VLF/LF)  

Rob Kavet gave a presentation on Perspectives on Low-Frequency Section of FCC NPRM: Human Exposure to Radiofrequency Electromagnetic Fields. The following conclusions can be drawn:

- Numerous concerns with ICNIRP 2010 Guideline (0-100 kHz);
- “dosimetric uncertainty” in ICNIRP Guideline:
  - Misapplied in an ad hoc fashion resulting in overly conservative RL 3 kHz (mismatch with BR);
  - In fact, dosimetric uncertainty is constrained by the ln-variance of the stimulus external field at threshold.
- Study of human subjects in pulsed fields provides valuable empirical data applicable to guideline/standard setting;
- Ideally, safety factors should be driven by the ln-std dev of the stimulus field at threshold;
- ICES’s use of divisors of 3 to derive safety factors very conservative (hindsight) but based on prior observations of electrostimulation.

The presentation can be found in Attachment 11.

d) Contact current limits alignment with E-field ERLs  

Rob Kavet and Ric Tell presented a status update on Revisions to Contact Current ERLs (0-110 MHz) in IEEE Std C95.1TM-2019.

Ric concluded with a talk on a measurement system for measuring body currents.

The presentation can be found in Attachment 12.

10. Future C95.1 revision  

The subjects for the revision were covered in the briefs given during the meeting and the following discussions.

11. Other New Business  

There was no further discussion and no action item.

12. Date and Place of Next Meeting  

Will be decided depending on the developments on the COVID-19 situation. Tentative the meeting will be held in the last week of January 2021. Either in person in Chandler AZ or online.

13. Adjourn  

There being no further business, the meeting was adjourned at 17:15 h GMT, the motion was moved by Marv Ziskin and seconded by Antonio Faraoe.
# Sign-in Sheet

**SC3/4 Meeting, 03/04 June 2020, WebEx IEEE**

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Approved 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

Day 1:

Electronic meeting
Wednesday June 3rd, 2020

Pacific Coast, USA 6:00-8:00
East Coast, USA 9:00-11:00
GMT 13:00-15:00
Central Europe 15:00-17:00
Tokyo, Japan 22:00-0:00

1. Call to Order
   Legros
2. Welcome Participants
   Legros
3. Approval of Agenda
   Legros
4. Approval of the Minutes (22 January 2020 Meeting)
   Legros
5. Call for Patents*
   Legros
6. Chairmen's Reports
   SC3/SC4 Co-chairs
   a) Update on the revision of ICNIRP guidelines on HF fields
      Hirata
   b) ELF/RF literature surveillance
      Elder
   c) Report on the C95.1-2345-2014 revision
      Escobar
**International Committee on Electromagnetic Safety**

**Day 2:**

**Electronic meeting**  
**Thursday June 4th, 2020**

**Pacific Coast, USA 6:00-8:00**  
**East Coast, USA 9:00-11:00**  
**GMT 13:00-15:00**  
**Central Europe 15:00-17:00**  
**Tokyo, Japan 22:00-0:00**

8. Vote on Corrigendum 2  
9. Technical Presentations
   a) Non-invasive brain stimulation; relevance to standards  
   b) A summary on a description of ICNIRP’s new RF guideline with a comparison to ours  
   c) A summary of the FCC’s NPRM and associated issues (VLF/LF)  
   d) Contact current limits alignment with $E$-field ERLs

11. Future C95.1 revision  
12. Other New Business  
13. Date and Place of Next Meeting  
14. Adjourn

*Participants have a duty to inform the IEEE of holders of essential patent claims if they or their affiliations hold such claims. Check the web link on the agenda for more details. If anyone in this meeting is personally aware of any patent claims that are potentially essential to implementation of the proposed standard(s) under consideration by this group and that are not already the subject of an Accepted Letter of Assurance, please speak to the committee chair today.*

The IEEE SA patent policy is explained at the following links:


https://development.standards.ieee.org/myproject/Public/mytools/mob/slideset.ppt

Thank you for your cooperation.

Co-Chairs, SC3 and SC4
Approved Meeting Minutes

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and
IEEE/ICES TC95 Subcommittee 4
Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz

0900 – 1530 h
Wednesday, 22 January 2020
Motorola Solutions, 8000 West Sunrise Blvd, Plantation, FL 33322

1. Call to Order  Ziskin
The meeting was called to order by Marv Ziskin at 0920 h

2. Introduction of those Present  All
Each of the attendees introduced her/himself.
(See Attachment 1 for list of attendees.)

3. Approval of Agenda  Ziskin
The proposed agenda was approved
Following a motion by Tell that was seconded by Johnson, the agenda was unanimously approved. (See Attachment 2.)

4. Approval of the Minutes (7 August 2019 Meeting)  Ziskin
The Minutes of the meeting held on 7 August 2019 in Santa Rosa (CA) were discussed. There were a couple of editorial comments by Wessel and Chou.
The minutes were modified accordingly and following the discussion, Glembo moved to approve the August 2019 SC3/SC4 minutes. The motion was seconded by Fisher sr. The motion passed unanimously. (See Attachment 3).

5. Discussion of Patent Concerns  Ziskin
SC4 Chairman Ziskin made a “call for patents” relating to the work performed by members of SC3 and SC4 in making standards. (See Attachment 4). The chairman asked the SCs if there were any such patents assigned to SC members; there was none.

SC4 Chairman Ziskin presented the report (see attachment 5).
- Ziskin announced the new co-chair of SC3/4 being Alexandre Legros, he is the successor of Kevin Graf who moved to the FCC.
- Major SC3/4 tasks were reviewed, the most important of which was the approval of the corrigenda by IEEE and the insertion of the comments. The new standard was approved by IEEE on October 3rd 2019. Following publication on October 4th.
Ziskin expressed his special thanks to the Editorial Working Group, with special thanks to Antonio Faraone and Pat Roder (IEEE staff). Furthermore he thanked Joe Elder and Antonio Faraone for their work on the literature database, surveillance and review.

Following the approval of C95.1-2019, advertisement was performed by means of announcement to Major Regulatory Bodies, International Web Sites and a publication in IEEE Access with a synopsis of the new standard. Ziskin expressed his thanks to the authors and special thanks to C-K Chou and Ric Tell for their work on the synopsis.

Ziskin addressed the release of FCC Proposed Rule Making on Exposure Limits being “Resolution of Notice of Inquiry, Second Report and Order, Notice of Proposed Rule Making, and Memorandum Opinion and Order”. The document led to the generation of a response from ICES to FCC to express the concerns of ICES wrt the FCC proposal. An initial draft was produced and distributed among the SC members. Additional input is needed and ICES consensus approval is necessary, followed by IEEE Legal Approval.

Niels Kuster raised the question about the publication date of the FCC document. Bob Cleveland answered that there is no timetable yet, the document is also not yet registered. He also provided a sample format that can be used for comments to FCC (see Attachment 6)

On July 2019, Ric Tell was awarded with the 2019 Distinguished Service Award from Health Physics Society for his Accomplishments of fundamental importance to the practice, acceptance, and advancement of Non-Ionizing Radiation Protection.


a) ELF/RF Literature surveillance

Joe Elder presented his report on the literature surveillance, currently the database holds 7344 citations of which 91.7% consists of a full PDF file. In the last 2 years 535 papers were added. The details of the brief can be found in Attachment 7.

Amongst the publications are four recent epidemiology papers on RF exposure and cancer. These were highlighted by Joe Elder and can be found in Attachment 8.

b) ELF/RF Literature review

Both Bob Cleveland and Ric Tell presented their view on the difficulties they experience with spatial averaging and the limits set for local body exposure. Cleveland raised the question “could there be confusion over the meaning of ‘local,’ ‘localized,’ and/or partial body exposure?” and concluded that the terms could be mixed up.

Tell gave a presentation on a Working Group on spatial averaging from 22 years ago and concluded with the following questions:

- Should appropriateness of spatial averaging of incident fields relative to whole-body SAR be further evaluated?
- Does the ‘discontinuity’ in averaging area at 6 GHz result in any detriment relative to preventing an exposure hazard?
- Is specifying only a spatial peak value of local field along with a WBA value below 6 GHz sufficient for safety?

Their presentations were followed by a general discussion. In Attachment 9 & 10 the presentations can be found.

c) Update on the revision of ICNIRP guidelines on HF fields

Aki Hirata briefed the latest information on the revision on ICNIRP RF guidelines, the commission is waiting for the 2nd round of approval, there were some editorial issues. The limit lines are now very close to the IEEE exposure limits.

On the LF ICNIRP guidelines that date from 2010 he mentioned that in the ICNIRP May meeting an update of the LF guideline will be on the agenda.
d) Update on the draft C95.1 paper for IEEE Access

C-K Chou gave a summary on the history of C95.1 and how advertisement of the standard was taken care of. The publication of latest version of the standard lead to the publication of a synopsis of the document in the IEEE journal IEEE-Access, the synopsis can be found here: https://ieeexplore.ieee.org/document/8910342

e) Update on letters to US government agencies

Jafar Keshvari gave an update of his activities in the Communication with US regulatory bodies about C95.1 publication & FCC’s Request for ICES Input. The presentation contains a list of countries that have used IEEE or FCC limits. In total, regulatory communication about the C95.1 publication was sent to 121 countries all over the world.

8. Discussion on Future Changes for C95.1

Bob Kavet presented his view on the near-term priorities for SC-3. These are:
- Identify criteria for identifying relevant CNS effects, exclusive of magnetophosphenes.
- Incorporate anatomical modeling into determining effect thresholds and ERLs;
- Harmonize contact current with electric field ERLs.
- Revisit statistically-based safety factors.
- Harmonize with ICNIRP?
- Format of ICES Standard 95.1 Content

The presentation was followed by a general discussion. Bob Kavet thanked Kevin Graf being the co-chair of SC-3 and welcomed Alexandre Legros as the new co-chair.

Marv Ziskin asked what a new safety factor for PNS would be, based on the new data being presented. Bob Kavet indicated that the safety factor could be lowered to approximately half of the current safety factor.

Ric Tell opened a discussion on the apparent inconsistency between E-field limit and contact/induced current limits. If they were to be harmonized, that would implicate a significant change in either the E-field limit (much lower) or an increase in the limits in contact/induced current. The discussion did not result in a final conclusion on how to proceed. In Attachment 11 the presentation can be found.

9. Technical Presentations

a) Highlights of the GLORE 2019 Annual Meeting in Lima

C-K Chou presented a review of the GLORE 2019 meeting. GLORE (Global Coordination of Research and Health Policy on RF Electromagnetic Fields) is a coordination action initiated by Japan and Korea in 1997 and joined by Europe and then by USA, Australia and Canada. Each year scientists and policy authorities from GLORE delegations take part in this meeting. The highlights of the meeting can be found in Attachment 12.

b) Temperature elevation from High Fluence Pulses

Niels Kuster presented findings on Consistency of EM Exposure Safety. Frameworks for Localised and Pulsed Exposure >6GHz. The following topics were addressed:
- spatial averaging
- temporal averaging
- responses to criticisms

The presentation was followed by a general discussion. In Attachment 13 the presentation can be found.
c) Thermal Analysis of Averaging Time in Radio-Frequency exposure

Ken Foster presented a brief on the effect of short, high-fluence MM-wave pulses being able to cause large temperature spikes. The presentation was followed by a general discussion. In Attachment 14 the presentation can be found.

d) My visit with Dr. Sol Michaelson

Ric Tell presented his experience on a visit with Dr. Sol Michaelson who was an important contributor to data related to heating effects of exposure to electromagnetic fields by doing experiments on dogs. The brief can be found in Attachment 15.

10. Presentation of Awards

For their contribution to completing the C95.1 the following persons were rewarded with an IEEE Award:
Bob Cleveland, David Maxson, Jerry Bushberg, Antonio Faraone, Joe Elder, Rob Kavet, Ric Tell, Aki Hirata, C-K Chou, Peter Zollman, Ron Peterson and Marv Ziskin.

11. Other New Business

There was no further discussion and no action item.

12. Date and Place of Next Meeting

Friday, June 19th 2020 in Newbury, United Kingdom.

13. Adjourn

There being no further business, the meeting was adjourned at 1530 h.
Chairman’s Report

SC – 3 & 4

June 3-4, 2020
Teleconference
SC – 3: Safety Levels 0 Hz to 3 KHz
   Co-Chairs: Rob Kavet
              Alexandre Legros

SC - 4: Safety Levels 3 KHz to 300 GHz
   Co-Chairs: Art Thansandote
              Marv Ziskin

Secretary:
   Auke Visser
Kevin Graf

My new business email address:

kevin.graf@fcc.gov
Major Tasks of SC – 3/4

C95.1-2019  Safety Standard (0 Hz – 300 GHz)
C95.1-2019  Corrigendum No. 1 to Correct all Errors
C95.1-2019  Publication – Published Version
Announcements to Major Regulatory Bodies
Synopsis of C95.1-2019
Revision of Synopsis
Synopsis Published
Letter to FCC re New Regulations
C95.1-2019 Corrigendum No. 2
Progress on Standards
Editorial Working Group (EWG)

- Bill Bailey
- Ralf Bodemann
- Bob Cleveland
- C-K Chou
- Antonio Faraone
- Ken Foster
- Aki Hirata
- Rob Kavet
- Alexandre Legros, Chair
- David Maxson
- John Opsepchuk
- Pat Reilly
- Ric Tell
- Art Thansandote
- Marv Ziskin
- Peter Zollman
Progress on Standards

Invaluable Help from IEEE Staff

Thanks to Patricia Roder
Progress on Standards

All C95.XX Standards are now available free of charge.

https://ieeexplore.ieee.org/browse/standards/get-program/page/series?id=82

Thanks to

US Air Force,
US Army
US Navy
Synopsis of IEEE Std C95.1™-2019 “IEEE Standard for Safety Levels With Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz”

IEEE International Committee on Electromagnetic Safety Technical Committee 95+

ABSTRACT The newly released IEEE Std C95.1™-2019 defines exposure criteria and associated limits for the protection of persons against established adverse health effects from exposures to electric, magnetic, and electromagnetic fields, in the frequency range 0 Hz to 300 GHz. The exposure limits apply to persons permitted in restricted environments and to the general public in unrestricted environments. These limits are not intended to apply to the exposure of patients by or under the direction of physicians and care professionals, as well as to the exposure of informed volunteers in scientific research studies, or to the use of medical devices or implants. IEEE Std C95.1™-2019 can be obtained at no cost from the IEEE Get Program: https://ieeexplore.ieee.org/document/8859679.

INDEX TERMS Non-ionizing radiation protection, radio frequency (RF), RF exposure, RF safety, dosimetric reference limit (DRL), exposure reference level (ERL), induced and contact currents, specific absorption rate (SAR), electric fields, magnetic fields, electromagnetic fields, (epithelial) power density, electrostimulation, general public, restricted environment, unrestricted environment.

BACKGROUND In 1960, the American Standards Association approved the initiation of the Radiation Hazards Standards Project under the co-sponsorship of the US Department of the Navy and the Institute of Electrical and Electronics Engineers, Incorporated (IEEE), (called the “Institute of Radio Engineers (IRE)” at the time). The first C95.1 standard was published in 1966. In 2003, the IEEE Standards Association Standards Board approved the name “International Committee on Electromagnetic Safety (ICES)” to better reflect its international membership as well as the scope of its Technical Committees (TC): TC34, addressing compliance assessment methods, and TC25, addressing exposure safety. The scope of IEEE ICES TC25, which developed IEEE Std C95.1™-2019, is “Development of standards for the safe use of electromagnetic energy in the range of 0 Hz to 300 GHz, relative to the potential hazards of exposure of man, volatile materials, and explosive devices to such energy. It is not intended to include infrared, visible, ultraviolet, or ionizing radiation. The committee will coordinate with other committees whose scopes are contiguous with ICES.” There are six TC25 Subcommittees, each of whose area of responsibility is described as follows in correspondence with its designated Subcommittee (SC) number:

SC 1: Techniques, Procedures, Instrumentation, and Computation
SC 2: Terminology, Units of Measurements, and Hazard Communication
SC 3: Safety Levels with Respect to Human Exposure, 0 Hz to 3 kHz
SC 4: Safety Levels with Respect to Human Exposure, 3 kHz to 300 GHz
SC 5: Safety Levels with Respect to Electromagnetic Devices
SC 6: EMF Modeling and Dosimetry

IEEE Std C95.1™-2019 [1] was prepared by SC 3 and SC 4. This synopsis is only a reference document and it is not designed to replace the standard. For a better understanding of the C95.1 standard, please download a free copy through the IEEE Get Program™: https://ieeexplore.ieee.org/document/8859679. Non-IEEE members will have to...
Progress on Synopsis

Special Thanks to The Authors:

For those FCC exposure limit followers here is the long-awaited release of:

Resolution of Notice of Inquiry,
Second Report and Order,
Notice of Proposed Rule Making, and Memorandum Opinion and Order.
FCC Proposed Rule Making

Generation of Letter from ICES to FCC

Initial Draft Produced by:
C-K Chou
Ric Tell
Rob Kavet
Ken Foster
David Maxson
Marv Ziskin

Significant Additional Input:
Antonio Faraone
Bob Cleveland
Bob Weller

Additional Step:
IEEE Legal Approval
Submission to FCC
International Committee on Electromagnetic Safety

May 29, 2020

Marlene H. Dortch, Secretary
Federal Communications Commission
Office of the Secretary
445 12th Street, SW
Washington, DC 20554

Dear Ms. Dortch,

The IEEE International Committee on Electromagnetic Safety submits the attached comments to the Notice of Proposed Rulemaking in ET Docket 19-226, "Targeted Changes to the Commission’s Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields."

We hope that our comments will be helpful.

Sincerely,

Jafar Keshvari, Chairman, IEEE/ICES
Jafar.keshvari@aalto.fi

Adjunct Professor of Bio-electromagnetics
Aalto University, Helsinki-Finland
Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of:
Targeted Changes to the Commission’s Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields
ET Docket No. 19-226

Comments of the IEEE International Committee on Electromagnetic Safety on the
NOTICE OF PROPOSED RULE MAKING

May 29, 2020

The Institute of Electrical and Electronics Engineers (IEEE) International Committee on Electromagnetic Safety (ICES) is pleased to respond to the Targeted Changes to the Commission’s Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields. We appreciate the Commission’s responsibility to maintain safety limits that are based on the best available scientific evidence.

ICES is composed of experts from many fields, including engineering, medicine, biology, and public health. Membership is open to all interested parties internationally. ICES develops standards and recommended practices relating to the safe use of electromagnetic energy, and its standards development process, in accordance with IEEE rules, is rooted in consensus, due process, openness, rights to appeal, and balance. ICES adheres to and supports the principles and requirements of the World Trade Organization’s (WTO) Decision on Principles for the Development of International Standards, Guides and Recommendations [https://standards.ieee.org/develop]. ICES maintains a scientific-literature database and conducts an ongoing evaluation of new publications on the subject of human exposure to radiofrequency (RF) electromagnetic fields.

ICES responds to the Commission’s proposals. The following position statements represent the views of ICES. They do not necessarily represent the views of IEEE as a whole, its global membership, or other IEEE Organizational Units.
In summary

Item 1: **VLF/LF Limits.** The FCC has proposed to adopt limits similar to the ICNIRP 2010 guidelines at frequencies between 3 kHz and 10 MHz. ICES believes that such a proposal lacks clear and compelling scientific justification, and recommends that the Commission adopts an alternative such as IEEE Std C95.1™-2019. Unlike the ICNIRP guidelines, the IEEE standard provides correspondence between external exposure limits and internal dose limits, such that compliance can be conducted accurately with a straightforward environmental measurement. The Commission’s proposed approach, lacking this correspondence, may likely impose restrictions that could unnecessarily burden operators in this spectrum.

Item 2: **Localized Exposures above 6 GHz.** ICES recommends that the FCC adopt a more conservative curve for localized exposure limits above 6 GHz.

Item 3: **Averaging Time.** The choice of averaging times in Table 3 of the FCC Notice of Proposed Rulemaking is based on a goal of limiting the peak temperature rise in tissue from an “impulse.” This proposal may be overly conservative, inefficient, and inconsistent. A simple remedy is to limit the fluence for brief, high-fluence pulses, and to apply a 6- or 30-minute averaging time to waveforms lacking high-fluence pulses. In addition, questions may be raised by the potentially inconsistent whole-body averaging times set forth in Table 1 of 47 CFR §1.1310(e).

Item 4: **Averaging Area above 6 GHz.** The power density averaging area of 1 cm² is based on an earlier version of the IEEE C95.1™ standard, IEEE C95.1™-1991, which was superseded by IEEE C95.1™-2005, and again by IEEE C95.1™-2019. Adopting the updated averaging area of 4 cm² and the SAR limits of the IEEE C95.1™-2019 standard (as well as the 2020 ICNIRP Guidelines) would not only reflect the underlying science based on substantial improvements in RF dosimetry over the last two decades, but would also avoid a discontinuity at 6 GHz caused by the transition from spatial-peak SAR to localized power density limits.

Item 1: **Frequencies between 3 kHz and 100 kHz**

Excerpts from FCC Notice Paragraphs 122-124

122. ...We noted that some inductive wireless chargers operate at frequencies below 100 kHz, and Commission staff has been approached by parties seeking guidance on how to determine compliance for wireless car chargers generally operating at similarly low frequencies. We are aware of three extant guidelines for RF exposure that extend to frequencies below 100 kHz: ICNIRP 2010, IEEE Std C95.1™-2005, and more recently, Health Canada Safety Code 6 (2015). All of these guidelines are aimed at prevention of electrostimulation due to RF electric fields induced internally within the human body in the
C95.1-2019 Corrigendum 2

Discovery of errors:
in Figures 1 and 2
of C95.1-2019
C95.1-2019 Corrigendum 2

Figure 1 — Graphical representations of the ERLs of Table 2, Table 3, and Table 4 for electric and magnetic fields—persons in unrestricted environments

**Original**

**Corrected**

Attachment 4
C95.1-2019 Corrigendum 2

Figure 2 — Graphical representations of the ERLs of Table 2, Table 3, and Table 4 for electric and magnetic fields—persons in restricted environments

Original

Corrected
Discovery of errors in Figures 1 and 2  
Correction of Figures 1 and 2  
Application for Project Authorization Request (PAR)  
Awaiting Approval of PAR  
SC 3-4 Vote  
TC95 Vote  
SCC39 AdCom Vote  
Formation of IEEE-SA Ballot Group  
IEEE Mandatory Editorial Coordination  
IEEE-SA Vote  
Submission of Cor 2 to IEEE RevCom for Approval  
Approval of Cor 2 by IEEE SASB  
Publication of C95.1-2019 Corrigendum No. 2

April 15
April 16
April 22
June 3
June 4
June 19
June 22
June 23 – July 8
June 23 – July 8
July 8 – Aug 7
Aug 10
Sept 24
Last Quarter of 2020
Friendly Warning

Don’t send .docm files as attachments to email
ICNIRP update

Akimasa Hirata
Nagoya Institute of Technology
Special Issue in Health Physics

• Principles for Non-Ionizing Radiation Protection - Health Phys 118(5):477–482; 2020
• Guidelines for Limiting Exposure to Electromagnetic Fields (100 kHz to 300 GHz) - Health Phys 118(5):483-524; 2020. (This publication was published ahead of print in March 2020).
• ICNIRP Note: Critical Evaluation of Two Radiofrequency Electromagnetic Field Animal Carcinogenicity Studies Published in 2018 - Health Phys 118(5):525-532; 2020. (This publication was published ahead of print in 2019).
• Gaps in Knowledge Relevant to the “Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz – 100 kHz)” - Health Phys 118(5):533-542; 2020
• Comments on the 2013 ICNIRP Laser Guidelines - Health Phys 118(5):543-548; 2020
• Light-Emitting Diodes (LEDs): Implications for Safety - Health Phys 118(5):549-561; 2020
• Information on LED Protection
• Intended Human Exposure to Non-Ionizing Radiation for Cosmetic Purposes - Health Phys 118(5):562-579; 2020
Workplan of ICNIRP 2020-2024

Will be discussed in the end of June. Tentative discussion includes
1. LF guidelines
2. Static magnetic field
3. Laser guidelines
etc.

Additional information and corrigendum of RF guidelines may be published in one year or so.
Assessment of local ERL in LF

• IEEE C95.1-2019 standard (also C95.6-2002 standard) mentions about an ellipsoidal induction model for LF exposure.

• Different (exposure) reference levels are set for different body parts; trunk versus limbs.

• For RF exposures, reference level for local exposure has been newly introduced in IEEE C95.1-2019 and ICNIRP guidelines (2020) for practical assessment.

• Consistency between exposure guidelines/standard as well as different frequency range is needed.
# Necessity of local ERL in LF

<table>
<thead>
<tr>
<th>Frequency</th>
<th>ICNIRP</th>
<th>IEEE</th>
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<tr>
<td>LF</td>
<td>Not yet considered</td>
<td>IEEE C95.6 (2002) RL depends on body parts</td>
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<tr>
<td>RF</td>
<td>ICNIRP (2020) RL is relaxed by sqrt (5)</td>
<td>IEEE C95.1 (2019) RL is relaxed approx. by sqrt (5) though dependent on frequency range</td>
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PC95.1-2019/Cor 2-2020™/D1
Draft Standard for Safety Levels with
Respect to Human Exposure to
Electric, Magnetic, and
Electromagnetic Fields, 0 Hz to 300
GHz
Corrigenda 2

Sponsor
IEEE International Committee on Electromagnetic Safety (SCC39)

Approved <XX MONTH 20XX>
IEEE-SA Standards Board

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Piscataway, NJ 08854, USA

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Replace Figure 1 with new Figure 1 as shown:

- Electric field strength (V/m)
  - 5000 V/m
  - 614 V/m

- Magnetic flux density (mT)
  - 353 mT
  - 118 mT
  - 0.904 mT
  - 1.13 mT
  - 0.205 mT

Frequency (Hz)
Replace Figure 2 with new Figure 2 as shown:

- Electric field strength
  - 20,000 V/m
  - 18,420 V/m
  - 353 mT
  - 2.71 mT
  - 1.13 mT
  - 0.615 mT

- Magnetic flux density (Limbs)
- Magnetic flux density (Head and torso)

Frequency (Hz)
Non-invasive brain stimulation; relevance to standards

Marom Bikson

June 4, 2020

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
Disclosure

The City University of New York: Patents on brain stimulation.
Soterix Medical: Produces tDCS and High-Definition tDCS.
Boston Scientific Neuromodulation: Scientific Advisory Board, Patents on brain stimulation
GlaxoSmithKline (GSK): Life Science Scientific Advisory Board
Mecta: Consultant
Halo Neuroscience: Scientific Advisory Board

Support

NIH (NIMH, NINDS, NCI, NIBIB) – BRAIN Initiative, NSF, Grove Foundation, Harold Shames, CCNY Fund, 21st Century Fund, “X”
Types of neuromodulation technologies (brain stimulation device)
Neuromodulation (brain stimulation) technologies

- Deep Brain Stimulation (DBS)
- Spinal Cord Stimulation (SCS)
- Transcranial Magnetic Stimulation (TMS)
- Electroconvulsive Therapy
- Transcranial Electrical Stimulation (tES)
- Transcranial Direct Current Stimulation (tDCS)
Neuromodulation (brain stimulation) technologies

- Few mA applied to implanted electrode
- 100s V/m
- Local (near implanted electrodes)
- 100s Hz
- Continuous (years, decades…)
- Acute (during stimulation) effects
Neuromodulation (brain stimulation) technologies

- 0.8 A applied to scalp
- ~100 V/m
- Several cm$^3$
- Limited number of pulses over seconds
- ~5 visits a week, up to several weeks
- Acute and Lasting (post-stimulation) effects on brain function
Neuromodulation (brain stimulation) technologies

- 1 mA applied to scalp
- 0.3-1 V/m
- Several cm$^3$
- DC, AC (1-100 Hz)
- 20 min session
- ~5 days per week, up to several weeks
- Acute and Lasting (post-stimulation) effects on brain function
tDCS: transcranial Direct Current Stimulation

Cathode (-) Electrode  Anode (+) Electrode

2 mA  20 minute session  “Anodal” / “Cathodal” refer to proximity of target
tDCS (pad electrode)  High Definition tDCS

M1-SO tDCS montage  Anatomical MRI derived models of current flow  4x1 HD-tDCS montage

Datta et al. Gyri-precise model of tDCS: Improved spatial focality *Brain Stim* 2001
Datta et al. Gyri-precise model of tDCS: Improved spatial focality *Brain Stim* 200!
Datta et al. Gyri-precise model of tDCS: Improved spatial focality *Brain Stim* 2001
Models of brain current flow have been validated (again and again).

Intra-cranial voltages during transcranial electrical stimulation:

Experimental recordings with subject specific MRI-derived models.

Huang et al. Measurements and models of electric fields in the human brain during tES. *Elife* 2017
Models of brain current flow have been validated (again and again)

Huang et al. Measurements and models of electric fields in the human brain during tES. *Elife* 2017
Safety in Neuromodulation
Risk and injury in Neuromodulation

- All neuromodulation interventions balance benefit with risk (e.g. IRB review, informed consent…)
- The lowest level of risk: Non-Significant-Risk (NSR), which is comparable to day to day activities
- Interventions that produce minor adverse events (e.g. transient itching) may be NSR
- A Serious Adverse Event (SAE) leads to permanent injury or requires medical intervention (to prevent permanent injury)
- If a SAE is anticipated, intervention is not NSR
- Risk is never “blanket” for a device, but for the total protocol (device, inclusion, exclusion…)

In neuromodulation: Changing the body (brain) is not necessarily an adverse event
Low-intensity transcranial electrical stimulation (few mA at scalp, tens of minutes, producing <1 V/m at brain) is considered “safe” (NSR) and ”tolerated”

- Safety: No evidence for serious adverse effect across hundreds of thousands of sessions

- Tolerability: Adverse events are mild and transient

Improper electrode set-up (e.g. metal on skin) can produce skin burns but is not considered an expected adverse event
How does (low intensity) neuromodulation change brain function?
Current flowing into the neurons **hyperpolarizes the membrane** and current flowing out of the membrane **depolarizes the membrane**

~100 V/m Polarization sufficient to trigger AP
~<1 V/m Polarization not sufficient to trigger
High-intensity Pulses

Supra-threshold (pacing)

Over-driving a neural network

Neuromodulation comes from secondary non-linear changes

Sub-threshold modulation

Low-intensity Waveforms

Deep Brain Stimulation

Motor Cortex Stimulation

Transcranial Magnetic Stimulation (TMS)
Supra-threshold (pacing)

High-intensity Pulses

Over-driving a neural network

Sub-threshold modulation

Low-intensity Waveforms
Supra-threshold (pacing)

High-intensity Pulses

Over-driving a neural network

Sub-threshold modulation

Low-intensity Waveforms
High-intensity Pulses

Supra-threshold (pacing)

Over-driving a neural network

Sub-threshold modulation

Low-intensity Waveforms

Transcranial Direct Current Stimulation (tDCS)

Interacting with specific activity in a neural network
Current flowing into the neurons **hyperpolarize the membrane** and current flowing out of the membrane **depolarizes the membrane**

\[
\begin{align*}
&\approx 100 \text{ V/m} \quad \text{Polarization sufficient to trigger AP} \\
&<1 \text{ V/m} \quad \text{Polarization not sufficient to trigger}
\end{align*}
\]
Neurons that are near threshold, don’t need a lot of polarization to fire

Threshold for Action Potential

Membrane Potential

Depolarization from synaptic input

Threshold for Action Potential

Depolarization from low-intensity stimulation

Spike Timing Amplifies the Effect of Electric Fields on Neurons: Implications for Endogenous Field Effects

Thomas Radman, Yuzhuo Su, Je Hi An, Lucas C. Parra,* Marom Bikson*
Sub-threshold modulation of oscillations

Ongoing ~25 Hz oscillations (in brain slice)

Baseline steady 25 Hz power

2 Hz low-intensity stimulation

Stimulation modulates ongoing activity

The Journal of Neuroscience, November 10, 2010 • 30(45):15067–15079 • 15067
Low-Intensity Electrical Stimulation Affects Network Dynamics by Modulating Population Rate and Spike Timing

Davide Reato, Asif Rahman, Marom Bikson, and Lucas C. Parra
Theta Burst Stimulation (TBS) generates LTP which is modulated by concurrent Direct Current Stimulation (DCS)

Kronberg et al. Direct current stimulation boosts Hebbian plasticity in vitro. *Brain Stim* 2019
Theta Burst Stimulation (TBS) generates LTP which is modulated by concurrent Direct Current Stimulation (DCS)

Kronberg et al. Direct current stimulation boosts Hebbian plasticity in vitro. *Brain Stim* 2019
A tutorial on a description of ICNIRP’s new RF guideline with a comparison to ours

C-K. Chou, Richard Tell, Kenneth R. Foster
Who Set EMF Exposure Standards?

- **ICNIRP** (International Commission on Non-Ionizing Radiation Protection)
  - guidelines developed by a committee of self-appointed experts, no industry representatives
  - formally recognized by WHO

- **IEEE-ICES** (International Committee on Electromagnetic Safety) TC95
  - large committee open to anyone with a material interest
  - about 130 members from 29 countries
  - open and consensus process
International EMF Safety Standards

- **ICNIRP (2020):** “provide a high level of protection for all people against substantiated adverse health effects from exposures to both short- and long-term, continuous and discontinuous radiofrequency EMFs.”

- **IEEE ICES C95.1-2019:** “provide science-based exposure criteria to protect against established adverse health effects in humans associated with exposure to electric, magnetic, and electromagnetic fields; induced and contact currents; and contact voltages over the frequency range of 0 Hz to 300 GHz.”
IEEE Exposure Standards History

1960: USASI C95 Radiation Hazards Project and Committee chartered

1966: USASI C95.1-1966 (2 pages)
   10 mW/cm² (10 MHz to 100 GHz)
   based on simple thermal model

1974: ANSI C95.1-1974 (limits for $E^2$ and $H^2$)

1982: ANSI C95.1-1982 (incorporates dosimetry)


2002: IEEE C95.6-2002 (0-3 kHz)

2006: IEEE C95.1-2005 (3 kHz-300 GHz) published on April 19, 2006
   (comprehensive revision, 250 pages, 1143 ref.)

2014: IEEE C95.1-2345-2014 (0-300 GHz) (NATO/IEEE agreement)

2015: NATO adopted C95.1-2345-2014

2019: IEEE C95.1-2019 (0-300 GHz) published on October 4, 2019
   (310 pages, 1550 ref.)
ICNIRP 2020 guidelines

- Guidelines (20 pages)
  - Basic restrictions (DRL)
  - Reference levels (ERL)
- Appendix A: Background Dosimetry (20 pages)
- Appendix B: Health Risk Assessment Literature (8 pages)
Differences in limits between ICNIRP 2020 Guidelines and IEEE C95.1-2019

Frequencies below 6 GHz
- Ric Tell

Frequencies above 6 GHz
- Kenneth Foster
Differences in Classification of EME Exposure

**IEEE**

Persons in unrestricted environments
Persons permitted in restricted environments
[Qualified individuals per C95.7]

**ICNIRP**

General public exposure
Occupational exposure

R Tell (6-4-2020)
Important distinction between IEEE and ICNIRP

**IEEE**
- ERL for persons permitted in restricted environments
- Safety program initiation level (all people)
- Safety program required

**ICNIRP**
- Occupational exposure limit
- General public exposure limit
- Safety program required
- Non-workers not permitted even if subject to safety program

The safety program assesses potential exposure levels, the relevant population, the risk of exposure, etc. and establishes relevant controls to limit exposure to less than the limit when necessary.
Numerical differences between exposure limits for IEEE & ICNIRP

Above 6 GHz, limits pretty much the same

Below 6 GHz, it’s a mess
Comparison of IEEE (2019) and ICNIRP (2020) Whole body & Local Exposure Limits

E-field (V/m), H-field (A/m), S (W/m²)

Frequency (MHz)

<6 GHz

>6 GHz

IEEE & ICNIRP Local Res/Occ

IEEE & ICNIRP WBA Res/Occ

IEEE & ICNIRP Local Ures/Pub

IEEE & ICNIRP WBA Ures/Pub

R Tell (6-4-2020)
A word about local exposure limits

History:
• Partial body
• Localized
• Local

What does local mean? Exposure at a point! At least, that is what was meant when the IEEE standard was revised.


ICNIRP 2020 local limits based on? [not precisely cited]
ICNIRP provides useful local field strength limits beyond the IEEE upper frequency of 400 MHz.

ICNIRP local exposure limits are relative to a point for frequencies < 6 GHz.

IEEE implies that local exposure is to be averaged over some undefined area in Annex D. This needs correction!
Restricted/Occupational

- IEEE S WB Res
- ICNIRP S WB Occ
- IEEE S Loc Res
- ICNIRP S Loc Occ

Power density (W/m^2)
Frequency (MHz)
Comparison of C95.1-2019 with ICNIRP (2020) 6-300 GHz

**Similarities**

- Same underlying philosophy (thermal)
- Overall very similar (harmonized)
  - Same averaging times
  - Same limits

**Differences**

- Differences in terminology
  - ICNIRP: General public/occupational Reference level/basic restriction
  - IEEE: Restricted/unrestricted ERL/DRL
- Different limits for high fluence mm-wave pulses
- Length: 42 pp. (ICNIRP) vs. 310 pp (IEEE)
Restricted/Occupational

- IEEE S WB Res
- ICNIRP S WB Occ
- IEEE S Loc Res
- ICNIRP S Loc Occ

Harmonized Limits

Local exposure
Whole Body exposure

Power density (W/m²)
Frequency (MHz)
<table>
<thead>
<tr>
<th>IEEE</th>
<th>ICNIRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted: 10 W/m² /30 min</td>
<td>10 W/m² /30 min</td>
</tr>
<tr>
<td>Restricted: 50 W/m² /30 min</td>
<td>50 W/m² /30 min</td>
</tr>
</tbody>
</table>
## Local Exposure, 6-300 GHz

**IEEE (ERL)**

<table>
<thead>
<tr>
<th>&gt; 6 min (averaged over 6 min)</th>
<th>&lt; 6 min</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Restricted Environments</strong></td>
<td></td>
</tr>
<tr>
<td>200 (6 GHz)</td>
<td></td>
</tr>
<tr>
<td>To</td>
<td></td>
</tr>
<tr>
<td>100 (300 GHz)</td>
<td></td>
</tr>
<tr>
<td><strong>Unrestricted Environments</strong></td>
<td></td>
</tr>
<tr>
<td>40 (6 GHz)</td>
<td></td>
</tr>
<tr>
<td>To</td>
<td></td>
</tr>
<tr>
<td>20 (300 GHz)</td>
<td></td>
</tr>
</tbody>
</table>

**ICNIRP (Reference Level)**

<table>
<thead>
<tr>
<th>&gt; 6 min (averaged over 6 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Occupational</strong></td>
</tr>
<tr>
<td>200 (6 GHz)</td>
</tr>
<tr>
<td>To</td>
</tr>
<tr>
<td>100 (300 GHz)</td>
</tr>
<tr>
<td><strong>General Public</strong></td>
</tr>
<tr>
<td>40 (6 GHz)</td>
</tr>
<tr>
<td>To</td>
</tr>
<tr>
<td>20 (300 GHz)</td>
</tr>
</tbody>
</table>
# Averaging Areas

<table>
<thead>
<tr>
<th>IEEE</th>
<th>ICNIRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 cm² 6-300 GHz</td>
<td>4 cm² (ERL, 6-300 GHz)</td>
</tr>
<tr>
<td>1 cm² &gt; 30 GHz</td>
<td>1 cm² (limits on fluence, 30-300 GHz)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>For small exposed areas (&lt;1 cm²) ERL can be exceeded by factor of 2 with averaging area of 1 cm²</td>
<td></td>
</tr>
</tbody>
</table>
# High-Fluence Pulses

## Table 3. Exposure Limits for Pulse Fluence

<table>
<thead>
<tr>
<th></th>
<th>Incident energy density $\text{kJ/m}^2$</th>
<th>Averaging area</th>
</tr>
</thead>
<tbody>
<tr>
<td>**ICNIRP (2020)****&lt;br&gt; (30&lt;$f_i$ &lt;300 GHz)</td>
<td>$275/f_i^{0.177} \times 0.36[0.05+0.95(t/360)^{0.5}]$&lt;br&gt; $275/f_i^{0.177} \times 0.72[0.025+0.975(t/360)^{0.5}]$</td>
<td>4 cm$^2$ (2 cm×2 cm)&lt;br&gt; 1 cm$^2$ (1 cm×1 cm)</td>
</tr>
<tr>
<td>Occupational</td>
<td><strong>General public</strong>&lt;br&gt; $55/f_i^{0.177} \times 0.36[0.05+0.95(t/360)^{0.5}]$&lt;br&gt; $55/f_i^{0.177} \times 0.72[0.025+0.975(t/360)^{0.5}]$</td>
<td>4 cm$^2$ (2 cm×2 cm)&lt;br&gt; 1 cm$^2$ (1 cm×1 cm)</td>
</tr>
<tr>
<td><strong>IEEE C95.1-2019</strong>&lt;br&gt; (30&lt;$f_i$ &lt;300 GHz)</td>
<td>$1 f^{0.5}$&lt;br&gt; $0.2 f^{0.5}$</td>
<td>1 cm$^2$ (fluence limit)&lt;br&gt; 1 cm$^2$ (fluence limit)</td>
</tr>
<tr>
<td>Restricted</td>
<td>Unrestricted</td>
<td></td>
</tr>
<tr>
<td><strong>FCC</strong></td>
<td>Occupational</td>
<td>18</td>
</tr>
<tr>
<td><strong>General Public</strong></td>
<td></td>
<td>18</td>
</tr>
<tr>
<td><strong>ICNIRP (2013) (laser)</strong>*&lt;br&gt; (2600 nm &lt; $\lambda$ &lt;1 mm)</td>
<td>$5.6 f^{0.25}$ (1 ns–10 s)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>diameter of 11 mm, $\lambda$ &gt;1.4 $\mu$m&lt;br&gt; diameter of 3.5 mm, $\lambda$ &gt;100 $\mu$m</td>
</tr>
<tr>
<td>(1400 nm &lt; $\lambda$ &lt;1 mm)</td>
<td>$1 \text{kW/m}^2 \cdot \text{t (10s -30000s)}$</td>
<td></td>
</tr>
</tbody>
</table>

*$f_i$ is frequency in GHz; $t$ is exposure time [pulse duration] in seconds. **Based on footnote 7 to Table 7 of ICNIRP (2020)[1] *** based on Table 8 of ICNIRP (2013) [42].
Perspectives on Low-Frequency Section of FCC NPRM: Human Exposure to Radiofrequency Electromagnetic Fields (ET Docket No. 19-226)

Rob Kavet

ICES SC3/4 Summer Meeting
June 4, 2020
## Two Non-Identical NPRMs

<table>
<thead>
<tr>
<th>Released Dec. 4, 2019</th>
<th>Federal Register, April 6, 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>“While each of the standards appear to provide appropriate $E_i$ guidelines, the ICNIRP 2010 guidelines are the most recent that are widely accepted internationally. <strong>Accordingly</strong>, we propose to adopt limits on $E_i$ similar to these ICNIRP 2010 guidelines.”</td>
<td>While each of the standards appears to provide appropriate $E_i$ guidelines, the ICNIRP 2010 guidelines are the most widely accepted from an international perspective. The Commission proposes to adopt limits on $E_i$ similar to the ICNIRP 2010 guidelines.</td>
</tr>
<tr>
<td>“…we do <strong>not</strong> propose to amend or extend our MPE limits on external fields.”</td>
<td>Clause omitted.</td>
</tr>
</tbody>
</table>
relevant for PNS effects (i.e., at 50 Hz, the factor used to convert the basic restriction for CNS effects to an external magnetic field exposure is 33 V m\(^{-1}\) per T, and for PNS effect 60 V m\(^{-1}\) per T. An additional reduction factor of 3 was applied to these calculated values to allow for dosimetric uncertainty).
Dose and Exposure Limits

- Electric Field (V/m RMS):
  - ICNIRP BR (2010)
  - IEEE DRL (2019)
  - HC BR (2015)
  - $f_c(\text{IEEE}) = 3.35 \text{ kHz}$
  - $f_c(\text{ICNIRP/HC}) = 3 \text{ kHz}$

- Magnetic Field (mT RMS):
  - ICNIRP RL (2010)
  - IEEE ERL (2019)
  - HC RL (2015)
  - $f_c(\text{IEEE}) = 3.35 \text{ kHz}$
  - $f_c(\text{ICNIRP/HC}) = 3 \text{ kHz}$
  - x4.2
  - x7.7
## ICNIRP vs ICES/IEEE

<table>
<thead>
<tr>
<th>Factor</th>
<th>ICNIRP</th>
<th>IEEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Threshold parameter</td>
<td>Cites peak value PNS threshold (rheobase) range in So et al. (2004) but applies it as an $RMS$ quantity for basic restriction.</td>
<td>Consistent in application of peak and $RMS$ quantities.</td>
</tr>
<tr>
<td>2) Criterion sensory response</td>
<td>Not explicitly stated for PNS; perception presumed.</td>
<td>Pain explicitly stated for PNS</td>
</tr>
<tr>
<td>3) Pain multiplier</td>
<td>Compares lowest percentile pain to median perception (20% difference); should be comparison of medians (~2x difference in source).</td>
<td>Assigns multiplier of 1.45 based on studies of human responses to various forms of electrostimulation.</td>
</tr>
<tr>
<td>4) Consistency of sensory criteria</td>
<td>Apparently, perception for PNS from $B$-field, but pain for contact current.</td>
<td>Consistent pain criteria.</td>
</tr>
</tbody>
</table>
## ICNIRP vs ICES/IEEE

<table>
<thead>
<tr>
<th>Factor</th>
<th>ICNIRP</th>
<th>IEEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>5) Safety factors</td>
<td>General Public <em>BR</em>: Applies an <em>ad hoc</em> reduction factor of 10 to the assigned dose threshold (4 V/m <em>RMS</em> at &lt;3 kHz); General Public Reference Level: due to “dosimetric uncertainty” adds an additional arbitrary reduction factor to arrive at 0.0267 mT <em>RMS</em> for <em>RL</em> VLF/LF.</td>
<td>Safety factor of 3 to protect no fewer than 1 in 100 in Restricted environments; additional factor of 3 for Unrestricted environments (worst case probability of ~1.6 in a million); based on studies of electrostimulation.</td>
</tr>
<tr>
<td>6) Correspondence of exposure limit with dose limit</td>
<td>An environmental measurement &gt;0.0267 mT &amp; &lt;0.11 mT (<em>RMS</em>) exceeds Reference Level, but is likely compliant with Basic Restriction; creates compliance issue.</td>
<td>Exposure and dose limits correspond to one another in the IEEE dose model.</td>
</tr>
<tr>
<td>7) Limbs</td>
<td>No exceptions for limb-only exposures; creates potential compliance issue.</td>
<td>Relaxed exposure limits for limbs (no vital organs).</td>
</tr>
</tbody>
</table>
Dosimetric Uncertainty: General Principle

Re-arranging the coupling equation at sensory threshold:

\[ B_{\text{Thresh}} = \frac{E_{\text{Thresh}}}{(CPN \times f)} \]

\[ \ln (B_{\text{Thresh}}) = \ln (E_{\text{Thresh}}) - \ln (C_{PN}) - \ln (f) \]

There is no reason to suspect \( E_{\text{Thresh}} \) and \( C_{PN} \) are correlated across a population sample. Then at a given \( f \),

\[ \sigma^2[\ln (B_{\text{Thresh}})] = \sigma^2[\ln (E_{\text{Thresh}})] + \sigma^2[\ln (C_{PN})] \]

⇒ Neither the ln-variances of \( E_{\text{Thresh}} \) or \( C_{PN} \) can exceed the ln-variance of the external stimulus at threshold \( (B_{\text{Thresh}}) \).

⇒ In other words, “dosimetric uncertainty” is bounded.

⇒ Then, \( \sigma[\ln (B_{\text{Thresh}})] \) determines the desired safety factor.
Human Subjects Study: Responses to MRI Pulses

Exposure
9 Pulse Widths
(50 µs to 1 ms)

2001
Health Effects and Safety of Intense Gradient Fields
John A. Nyenhuis, Joe D. Bourland, Alexander V. Kildishev, and Daniel J. Schaefer

Perception
Discomfort
Pain

N=84

attachment 11
Follow-on Analyses

2001
Health Effects and Safety of Intense Gradient Fields
John A. Nyenhuis, Joe D. Bourland, Alexander V. Kildishev, and Daniel J. Schaefer

2004
Dosimetry: Estimate PNS Rheobase for Perception

2005
Computation: Derive 60-Hz Exposure-Response
Dosimetry Study (So et al., 2004)

- “The computed electric fields...corresponding to peripheral nerve stimulation (PNS)...range from 3.8 [V/m] to 5.8 V/m for the fields exceeded in 0.5% of tissue volume (skin and fat of the torso).”
- “For trapezoidal pulses and the y-coil considered here, a rheobase of (18.8±0.6) T/s ...[was] estimated [Den Boer et al., 2002].”
- Then, \( C_{PN} = 2\pi \times \frac{3.8}{18.8} = 1.27 \) (V/m)/(T-Hz)
  - In the mid-range of published values;
  - Approximately equal to ICNIRP’s inferred \( C_{PN} \) of 1.2 (V/m)/(T-Hz).
Computational Study (Bailey & Nyenhuis, 2005)

Extrapolate to VLF/LF

60 Hz

47.94 mT (GM)

$\sigma \ln (B_{\text{Thresh}}) = 0.233$

$GSD = 1.262$

1%: 27.88 mT

35.57 mT

Percent Responding

0%

10%

20%

30%

40%

50%

60%

70%

80%

90%

100%

10

100

Magnetic Field, $B_{\text{Ext}}$ (mT RMS)

Frequency (Hz)

$B_{\text{Thresh}(60)} = 47.94$

$B_{\text{Thresh}(3,000)} = \left(\frac{f_1}{f_2}\right)B_{\text{Thresh}(60)} = 0.96$ mT

$f_1 = 60$ Hz

$f_2 = 3,000$ Hz
Normal Probability Plot of Perception Threshold at ≥3 kHz Based on Human Subjects Study

Median

ICNIRP <10^{-52}

Magnetic Field, $B_{\text{Ext}}$ (mT RMS)

Probability of Perception

IEEE

6x $\sigma$

0.96

0.82

0.71

0.56

0.47

0.40

0.35

0.32

0.29

0.26

0.24

0.22
Conclusions

• Numerous concerns with ICNIRP 2010 Guideline (0-100 kHz);
• “dosimetric uncertainty” in ICNIRP Guideline:
  – Misapplied in an *ad hoc* fashion resulting in overly conservative $RL \geq 3$ kHz (mismatch with $BR$);
  – In fact, dosimetric uncertainty is constrained by the ln-variance of the stimulus external field at threshold.
• Study of human subjects in pulsed fields provides valuable empirical data applicable to guideline/standard setting;
• Ideally, safety factors should be driven by the ln-std dev of the stimulus field at threshold;
• ICES’s use of divisors of 3 to derive safety factors very conservative (hindsight) but based on prior observations of electrostimulation.
Thank You!
One More Thing

- Mismatched $B$-field exposure limits $\geq 300$kHz;
- Electrostimulation $\geq 100$kHz technically relevant for low duty factor fields;
- But how low?
- Similar issue for dose
  - $BR = 135 * f$ V/m ($f$, MHz)
  - At 10 MHz, $BR = 1,350$ V/m
  - $SAR \sim 1,000$ W/kg
Revisions to Contact Current ERLs (0-110 MHz) in IEEE Std C95.1™-2019: Status Update

Rob Kavet
Ric Tell

ICES SC3/4 Summer Meeting
June 4, 2020
In a Nutshell

• The contact/induced current *ERLs* in Tables 12-14 address exposures to currents that arise from ambient electric fields;

• Therefore, the contact/induced current *ERLs* must be aligned (or harmonized) with the electric field *ERLs* (& RF *DRLs*);

• Presently, this is **not** the case;

• We intend to make recommendations for Tables 12 through 14.
Summary

• Top rows of Tables 12 & 13 are unnecessary: No source for “Induced, single foot”;

• Table 13 could be justifiably reduced to ≤100 kHz (now 5 MHz): Unpredictable duty factor;

• Tables 12 and 13 can be combined into a single table.

• For Table 14 (100 kHz – 110 MHz):
  – ...Top row ERLs (“Induced, each foot”) are incompatible with local DRLs and E-field ERLs, row 2 (“Contact, grasp”)-& 3 (“Contact, touch”) - ERLs are incompatible with E-field ERLs;
  – The temporal relationship between skin heating and RF touch currents is overlooked, resulting in overly-conservative ERLs.
Basic Scenario: Person in a Vertical Electric Field

- **Electric Field**: A field of force that exerts a force on moving charges. The diagram shows an electric field surrounding a person.

- **Person Grounded**: When a person is grounded, the current is conducted through the ground, and the current in the body $(I_{IND})$ is approximately equal to the contact current $(I_{sc})$.

- **Ungrounded**: When a person is not grounded, the current is dissipated through the body, and the current in the body $(I_{IND})$ is approximately equal to the contact current $(I_{sc})$.

Mathematically:

$$I_{IND} \approx I_{sc}$$
Progress on Recommendations Slowed

• Need to describe $I_{IND} \approx I_{SC}$ as functions of $E$-field and frequency from ELF up to (~30-40 MHz) and beyond resonance;
• Many published and unpublished studies have reported both measured and modeled $I_{IND} = fn(f,E)$;
• However, measured and modeled results are not consistent with each other;
• But first, need a common denominator for $E$-field coupling.
When $\lambda >>$ person’s height...

$$I_{IND} = 2\pi f \varepsilon_0 S_{Eff} E$$

OR

$$I_{IND} = 9.02 \times 10^{-5} f h^2 E \, \mu A$$

Note:

At $<\sim 25$ MHz, $\lambda > 30$ m

If $h = 1.75$ m, $S_{Eff} \approx 5$ m$^2$

Based on: Bracken, 1976; Deno, 1977
Electric Fields Induction at 60 Hz

Bracken, 1976

EMPIRICAL FITTED CURVE - $I_{sc}/E = 5.4h^2$

$= 9 \times 10^{-11} \times 60 \times h^2$

Deno, 1977

Maxwell's displacement current per unit area

$N=1$ mannequin

Equivalent charge collecting area

\[ I_{sc} = (\omega \varepsilon E)(\pi h^2 \tan^2 35.7^\circ) \]
\[ = 5.4 \times 10^{-9} h^2 E \]
Coupling Scales to Linear Dimensions Squared, but Angle Remains the Same

\[ h_1 = 1.8 \text{ m} \]
\[ h_2 = 0.9 \text{ m} \]
\[ I_{IND} \propto S_{Eff} \propto h^2 \]

\[ r_1 \]
\[ S_{Eff1} \]
\[ r_2 = 0.5r_1 \]
\[ S_{Eff2} = 0.25S_{Eff1} \]
Measured vs Modeled $E$-Field Induction

- Obs Meas
- Meas Fit
- Modeled
- Model Fit
- Dim-Find

$N=73; R^2=0.98$

$N=125; R^2=0.89$
Prolate Spheroid Surrogate

Durney letter to R. Tell, Jan 1979

Jokela et al., Health Phys 66:237, 1994

Identical to Durney

I = \frac{j\omega\varepsilon_0 (\varepsilon' - j\varepsilon'') E_0^i \pi b^2}{(\varepsilon' - 1)g_e + 1 - j\varepsilon''g_e}

g_e = \left(\frac{u}{2} - 1\right) \ln \left(\frac{u + 1}{u - 1} - 1\right)

u = \frac{a}{\sqrt{a^2 - b^2}}

Never Published

I_{sc} = \frac{\pi b^2 \varepsilon_0 \omega \varepsilon_r + j\varepsilon_r}{A_1} \frac{E}{\varepsilon_r - j\varepsilon''}
Durney/Jokela Equation

- Jokela et al., 1994: “...quasi-static approximation [of formula] becomes inadequate above 20 MHz. Due to the whole-body resonance the current should increase instead of decrease.”
- Yet the induction vs frequency curve for measured data starts trending upwards well below 20 MHz where quasi-static conditions would definitely apply.
Gandhi et al., 1985, 1986

- Estimated $I_{sc} = 10.8 \times 10^{-11} x h^2 x f x E$, as compared to Bracken & Deno in which $I_{sc} = 9.0 \times 10^{-11} x h^2 x f x E$ (20% difference);
- Did not imply a frequency effect below resonance.

- Wilen et al., 2001:
  Measured currents lower than Gandhi’s.
- “If the plate is large compared to the cross sectional area of the feet, the instrument might pick up electric fields directly from the sides.”
Further…

- Blackwell, 1990: “..PCM is a useful tool in evaluating the exposure..in close proximity to compact HF antennas..since it allows measurement of ankle current under normal working conditions.”
Conclusion (then Ric)

- Revisions to Tables 12 & 13 are straightforward, and both can be combined into a single table;
- For Table 14, harmonize contact current ERLs with:
  - E-field ERLs
  - Local (ankle SAR)
  - Define conditions for Grasp Contact;
- Progress toward complete recommendations paused to resolve differences between measurement and modeling data with respect to coupling angle vs frequency curves;
- In our opinion, circumstantial evidence suggests that the methodological artifact leads to the upward sloping shape of the measurement curve, BUT not completely resolved.
The Ric Tell Homemade Body Current Platform

Displacement current flows to ground via fringing fields and bypasses current sensing element.

Body current flows to bottom of foot. Charge is distributed over top plate.

Meter reads voltage across resistor that represents most, but not all of the current flowing from body to ground.

Top and bottom plates are connected with low impedance, non-inductive resistor.
Parallel plates devices
A current transformer
Comparison of Calculated and Measured Induced Body Currents
Barefoot Conditions - 27.12 MHz, E=14 V/m
Data acquired with 25 individuals at Brooks AFB, TX
November 1995
Thank You!