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.
   Following a motion by C-K Chou that was seconded by Peter Zollman, the agenda was unanimously approved. (See Attachment 2.)
   The IEEE Copyright Policy was presented and explained by the IEEE SA representative. (See attachment 3)

4. **Approval of the Minutes (03-04 June 2020 Meeting)**

   The Minutes of the virtual meeting held on 03 and 04 June by WebEx were discussed. Rob Kavet found some typo’s and misspellings in the minutes. They will be corrected accordingly.
   There were no additional comments.
   Marv-Ziskin moved to approve the June 2020 SC3/SC4 minutes with the aforementioned corrections. The motion was seconded by Art Thansandote. 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.
   The IEEE policy on copyrights was presented to inform the group about the subject. See attachment 4.

6. **Chairmen's Reports**

   SC3/SC4 Co-chairs

   - Major tasks of SC3/4 were highlighted. They consist of producing/revision of the Safety Standard C95.1 including corrigenda and the revision of the Military Safety
Standard C95-2345. Furthermore dissemination of the work to regulatory bodies, database and literature surveillance and harmonization with ICNIRP.

- The new revision of C95.1-2019 will emphasize on low frequencies from 0 Hz to 100 KHz. The project is led by Alexandre Legros and Rob Kavet. Already there has been much progress in the basic science for this subject. An editorial working group is established and will be expanded with Dr. Julien Modolo.
- The chair pointed to the availability of the standards through the IEEE GET program.
- In reply to the request of FCC wrt to the notice of proposed rule making comments were issued on May 29 2020. Up to now no response has been received. Kevin Graf (FCC) will give brief on the item later.
- Alexandre Legros presented two additional reporting points:
  - Dr. Julian Modolo and Marom Biksom were invited to join the Editorial Working Group for the revision of C95.1. They were introduced to the SC.
  - Report on the presentation held on the GLORE meeting held on November 9 2020. The presentation consisted of the current status of IEEE limits and the plans for next 10 years. Interactions with Rodney Croft (ICNIRP chair) wrt revision related to Low Frequency limits. Active involvement in and contribution to IRPA by means of chairing a taskforce that –within IRPA-assembles and coordinates all non-ionizing radiation sections of all national IRPA agencies into a visible effort of promotion of research in the non-ionizing radiation spectrum. This another opportunity to keep in contact with ICNIRP.
  - The BioEM 2021 will most likely not take place in June but likely in September as hybrid meeting (on-line, face2face)

The chairmen’s report can be found in attachment 5 and 6


a) ELF/RF literature surveillance  
Joe Elder reported that there has been little activity on work on the database because there is no contract in place with the Mobile and Wireless Forum for the past year. Action has been taken and a decision has been made to restart the contract. What is left is the paperwork to be able to continue for the next year. Currently there are approximately 7500 entries in the database.

b) Update on the revision of ICNIRP guidelines on HF fields  
Aki Hirata will chair this group and also subcommittee 6 members will be involved. ICNIRP is also considering to revise the guideline on static magnetic fields.

Rob Kavet asked two questions:
Q1: Are the any plans for further papers on the basics of low frequency dosimetry.
A1: Aki Hirata will coordinate the writing of a paper in SC6 together with ICNIRP.
Q2: What issues is ICNIRP looking for in the in the revision of the low frequency guideline?
A2: Up to now ICNIRP has not yet discussed what kind of effect should be protected for. Based on the discussion the dosimetry group will derive limits.

c) FCC 19-126 Second Report and Order: Summary and Status of Rule Changes  
Kevin Graf gave a presentation regarding the subject.
The presentation contained the following items about the rulemaking:
- Effective Dates
- Rule Changes/Framework and compliance overview
- Other Actions
- Guidance Documents

The presentation can be found in attachment 7.

Q1: Rob Kavet: Are there any new regulations to be expected in the very low frequency range?
A1: This rulemaking started some time ago and does not contain new rules wrt low frequencies. There is a notice of proposed rulemaking that may eventually result in implementation.

Q2: Joe Elder: What are the units in the formulas on separation distances used MPE-based exemption slide (14)
A2: Units are in meters (m)

Q3: Joe Elder: How big is the size of the FCC group working on the subject.
A3: Approximately 7 people that work in the branch, in areas ranging from laboratory work to people working on interference issues and RF exposure.

Q4: C-K Chou

d) Report on the C95.1-2345-2014 revision
Roel Escobar gave a presentation on the update of the C95.1-2345. It contains a table that compares exposure limit tables between C95.1-2345-2014 and C95.1-2019. Most of the differences are no showstoppers for the upcoming revision. The editorial committee will be formed.

8. Technical Presentations

a) Low-frequency E-field Issue
Rob Kavet gave a presentation on the Compatibility of Low-Frequency ERLs with DRLs. In the presentation the premise that spark discharge and contact current thresholds at E-Fields that induce in situ E-fields are lower than DRLs, is re-visited. The conclusions drawn were:
- Before taking any action to revise the IEEE standard, further dosimetry for PN would be advisable (CNS as well);
- If the PN DRL is exceeded by exposure to the E-Field ERL, then either,
  - The PN DRL would need to be raised, or
  - The E-Field ERL would need to be lowered, or
  - A bit of both.
- Revisions to E-Field ERLs are impractical, because e.g.,
  - They are continuous with E-Field ERLs into RF frequencies;
  - Compliance in power line ROWs could become an issue;
  - B-Field compliance would require re-examination.

The presentation can be found in attachment 8.

b) Lab results that may be considered in future revisions
Alexandre Legros gave a presentation on research and lab results that may be considered in future revisions of the standard. The research is split-up into five phases, in phase IV (2017-2020) the following topics were addressed:
- Frequency response for magnetophosphene perception in humans – 1 to 300 Hz up to 100 mT.
- Adaptation to the darkness and threshold for magnetophosphene perception – 20 and 60 Hz up to 100 mT – 40 minutes adaptation.
- Postural control (sway) and vestibular MF exposure – 20, 60, 90, 120 and 160 Hz Electric (2mA) and MF (up to 100 mT) stimulations of 5 sec duration.
- Subjective Visual Vertical as an indicator of vestibular performance and MF exposure – 20, 60, 90, 120 and 160 Hz Electric (2mA) and MF (100 mT) stimulations of 25 sec.
- In Phase V (2020-2024) Laboratory Duplication and Experimental studies will be performed, in this Phase the following subjects will be researched:
  - Oculo-vestibular reflex and local MF exposure up to 100 mT - Eye torsion under ELF-MF stimulation
  - Threshold for Peripheral Nerve Stimulation (PNS) - Threshold from ICNIRP and IEEE extrapolated at 50 and 60 Hz from higher freqs
    Aim: test the PNS threshold experimentally in humans at 50 - 60 Hz
  - Replication magnetophosphene perception threshold in humans’ study
  - Threshold for a direct impact on brain networks and functions - Working Memory and EEG tested under and after 50 and 60 Hz up to 100 mT. Synaptic modulations would be associated with modulation of memory performance

Summary:
- Magnetophosphenes publications on their way - Team priority – targeting contributing to Guideline/Standards evolutions (thresholds and mechanisms)
- ELF vestibular effects up to 100 mT will have been thoroughly investigated – Eye torsion study ready to start (Phase V)
- Steps towards magnetophosphenes replication initiated (pilot study half-way and new lab in place end of the spring) – data acquisition starts in the fall 2021
- CNS effects - WM and EEG testing synaptic modulations - will address both Guidelines/Standards and application perspectives
- PNS threshold will be the first at 50-60 Hz and will address a Guidelines/Standards gap – plan to start pilot data collection in the fall 2021 (PhD student recruitment planned)
- Involvement helping to shaping the next steps in LF Standards and Guidelines

The presentation was followed by a discussion where several questions from the group were answered and where several subjects from the presentation were explained in depth. The presentation can be found in attachment 9.

9. Future C95.1 revision

Priorities in terms of Low Frequencies:
- CNS effects
  - Transition from magnetophosphenes to transcranial magnetic/electric stimulation?
  - Goal: Dose- and Frequency-Response characteristics (not trivial)
  - Initial formulation of working group
- Incorporate anatomical modeling into determining effect thresholds and ERLs
  - CNS/Small neurons
  - PNS/Peripheral nerve stimulation
  - Heart (not critical at this time – higher stimulation threshold)

A planning for the future update was presented; see slide 57 of attachment 9

10. Other New Business

There was no further discussion and no action item

11. Date and Place of Next Meeting

The meeting will be held online on July 13 and 14, 2021.

12. Adjourn

There being no further business, the meeting was adjourned at 15:19 h GMT, the motion was moved by Marv Ziskin and seconded by Art Thansandote.
# Sign-in Sheet

SC3/4 Meeting, 18 January 2021, WebEx IEEE

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ICES

International Committee on Electromagnetic Safety

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:

Virtual meeting
Monday January 18th, 2021

East Coast, USA 8:00-10:00
Pacific Coast, USA 5:00-7:00
GMT 13:00-15:00
Central Europe 14:00-16:00
Tokyo, Japan 22:00 - 24:00

1. Call to Order

2. Welcome Participants

3. Approval of Agenda

4. Approval of the Minutes (3-4 June 2020 Meeting)

5. Call for Patents*

6. Chairmen's Reports

   a) ELF/RF literature surveillance
   b) Update on the revision of ICNIRP guidelines on LF fields
   c) FCC 19-126 Second Report and Order:
      Summary and Status of Rule Changes

   Legros
   Legros
   Legros
   Legros
   Legros
   SC3/SC4 Co-chairs
   Elder
   Hirata
   Kevin Graf
Day 2:

Virtual meeting
Tuesday January 19th, 2021

East Coast, USA 8:00-10:00
Pacific Coast, USA 5:00-7:00
GMT 13:00-15:00
Central Europe 14:00-16:00
Tokyo, Japan 22:00 - 24:00

   d) Report on the C95.1-2345-2014 revision Escobar

8. Technical Presentations
   c) Low-frequency E-field Issue Kavet
   d) Lab results that may be considered in future revisions Legros

9. Future C95.1 revision Kavet/Legros
10. Other New Business Kavet
11. Date and Place of Next Meeting Kavet
12. 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
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**
   
   SC4 Chairman Ziskin presented the report (see Attachment 4).
   - 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.


   a) 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.
See Attachment 5

   b) ELF/RF literature surveillance

1. 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.

   c) 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 June19th.
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  
   **Ziskin**

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  
   **Bikson**

   Marom Biksom presented his view on non-invasive brain stimulation. Several brain stimulation techniques were highlighted. Furthermore safety in Neuromodulation 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 Neuromodulation 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  
   **Chou/Tell/Foster**

   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.
c) 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 during the meeting in the briefs given 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 Faraone.
IEEE SA COPYRIGHT POLICY

November 2019
INSTRUCTIONS FOR CHAIRS OF STANDARDS DEVELOPMENT ACTIVITIES

The standards development group participants are advised that:

- IEEE SA’s copyright policy is described in Clause 7 of the IEEE SA Standards Board Bylaws and Clause 6.1 of the IEEE SA Standards Board Operations Manual;
- Any material submitted during standards development, whether verbal, recorded, or in written form, is a Contribution and shall comply with the IEEE SA Copyright Policy;
- The Secretary is instructed to record in the minutes of the relevant meeting:
- The foregoing information is provided and the copyright slides will be shown (or provided beforehand).
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- Prior to presentation or submission, you shall notify the Working Group Chair of previously Published material and should assist the Chair in obtaining copyright permission acceptable to IEEE SA.
- For material that is not previously Published, IEEE is automatically granted a license to use any material that is presented or submitted.
IEEE SA COPYRIGHT POLICY

- The IEEE SA Copyright Policy is described in the IEEE SA Standards Board Bylaws and IEEE SA Standards Board Operations Manual
  - IEEE SA Copyright Policy, see
    - Clause 7 of the IEEE SA Standards Board Bylaws
      - https://standards.ieee.org/about/policies/bylaws/sect6-7.html#7

- IEEE SA Copyright Permission
  - https://standards.ieee.org/content/dam/ieee-standards/standards/web/documents/other/permissionltrs.zip

- IEEE SA Copyright FAQs

- IEEE SA Best Practices for IEEE Standards Development

- Distribution of Draft Standards (see 6.1.3 of the SASB Operations Manual
Chairman’s Report

SC – 3 & 4

January 18-19, 2021
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
Major Tasks of SC – 3/4

C95.1-2019   Safety Standard (0 Hz – 300 GHz)
C95.1-2019 Corrigenda No. 1 and No. 2
C95.1-2345-2014   Military Safety Standard
Announcements to Major Regulatory Bodies
Published Synopsis of C95.1-2019
Letter to FCC re New Regulations
Data Base & Literature Surveillance
Harmonization with ICNIRP
C95.1-2019 Revision

Major Emphasis is now on Low Frequency

0 Hz to 100 kHz

Project Leaders

Alexandre Legros
Rob Kavet

Much Progress in Basic Science
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
Editorial Working Group (EWG)

Welcome to:

Dr. Julien Modolo

Project Leader of a special session with world leaders in non-invasive stimulation at the Brain Stimulation Conference in Dec 2021
ICES Data Base and Literature Review

Data Base & Literature Surveillance
Joe Elder

Literature Review
Antonio Faraone, Chair
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 other medical professionals, as well as to the exposure of non-human subjects 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/8659679.

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 Electronic Engineers, Incorporated (IEEE), (called the “Institute of Radio Engineers (IRE)” at the time). The first C95.1 standard was published in 1966. In 2001, 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); TC6, addressing compliance assessment methods, and TC95, addressing exposure safety. The scope of IEEE ICES TC95, 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 TC95 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 300 kHz
SC 4: Safety Levels with Respect to Human Exposure, 3 kHz to 300 GHz
SC 5: Safety Levels with Respect to Electro-Explosive 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 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/8659679). Non-IEEE members will have to

17546
Progress on Synopsis

Special Thanks to The Authors:

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John Osepchuk
Pat Reilly
Ric Tell
Art Thansdandote
Kenichi Yamazaki
Marv Ziskin
Peter Zollman
Federal Communications Commission (FCC)

Resolution of Notice of Inquiry,
Second Report and Order,
Notice of Proposed Rule Making, and Memorandum Opinion and Order.
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
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
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
Figure 2 — Graphical representations of the ERLs of Table 2, Table 3, and Table 4 for electric and magnetic fields—persons in restricted environments
<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
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<tbody>
<tr>
<td>Discovery of errors in Figures 1 and 2</td>
<td>April 15</td>
</tr>
<tr>
<td>Correction of Figures 1 and 2</td>
<td>April 16</td>
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<tr>
<td>Application for Project Authorization Request (PAR)</td>
<td>April 22</td>
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<td>Awaiting Approval of PAR</td>
<td>June 3</td>
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<td>June 22</td>
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<td>Formation of IEEE-SA Ballot Group</td>
<td>June 23 – July 8</td>
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<tr>
<td>IEEE Mandatory Editorial Coordination</td>
<td>June 23 – July 8</td>
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<tr>
<td>IEEE-SA Vote</td>
<td>July 8 – Aug 7</td>
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<tr>
<td>Submission of Cor 2 to IEEE RevCom for Approval</td>
<td>Aug 10</td>
</tr>
<tr>
<td>Approval of Cor 2 by IEEE SASB</td>
<td>Sept 24</td>
</tr>
<tr>
<td>Publication of C95.1-2019 Corrigendum No. 2</td>
<td>Last Quarter of 2020</td>
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C95.1-2019 Corrigendum 2

- C95.1-2019 / Cor 2- 2020
- Available without charge through IEEE Get Program
- Not combined with C95.1-2019
- Must be requested and downloaded separately.
C95.1-2345 Revision

- Military Safety Standard (C95.1-2345-2014)
- IEEE Standard for Military Workplaces--Force Health Protection Regarding Personnel Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz
- Initial Leader - B. Jon Klauenberg
- Revision Leader – Roel Escobar
Harmonization with ICNIRP

International Commission on Non-Ionizing Radiation Protection

Significant Interaction with ICES Members

Aki Hirata on ICNIRP Commission Membership

Many ICES members have been Consultants and Presenters at ICNIRP Conferences

ICES interaction invited in early stages of setting limits
Additional reporting points

- EWG invitations to plan

  Julien Modolo invited to join and help building the EWG
  Marom Bikson on the EWG (non-invasive brain stimulation expert)
  Individuals in the domain will be invited to join the team
- GLORE meeting – presentation of a 10-year action plan (aligned with previous presentations from Kevin and Rob)

- Interactions with Rodney Croft (ICNIRP chair) in regards of Low Frequency revisions

- IRPA Involvement: International Non-Ionizing-Radiation coordination task group

- Info BioEM2021
FCC 19-126 Second Report and Order: Summary and Status of Rule Changes

IEEE TC95 SC3-4
January 18, 2021

Office of Engineering and Technology
Federal Communications Commission
Outline

FCC 19-126 Rulemaking
  – Effective Dates
  – Rule Changes
    • Exemption
    • Evaluation
    • Mitigation
  – Other Actions
  – Guidance Documents
FCC 19-126 Rulemaking

Second Report and Order of FCC 19-126 includes changes to the RF exposure rules
- Appeared April 1, 2020 in the Federal Register (FR) with correction, delay of effective date published in FR on June 2, 2020
- Follows from proposals in FCC 13-39 (docket no. 03-137)
- Changes to RF exposure rules in 47 CFR 1.1307, 1.1310, 2.1091, 2.1093
- Conforming edits to 47 CFR 1.4000, 2.1033, and Parts 15, 18, 22, 24, 25, 27, 73, 90, 95, 97, 101

FCC 19-126; Proposed Changes in the Commission’s Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields; docket no. 03-137 (Terminated); Adopted: November 27, 2019; Released: December 4, 2019

85 FR 18131-18151; (https://www.govinfo.gov/content/pkg/FR-2020-04-01/pdf/2020-02745.pdf)
85 FR 33578; (https://www.govinfo.gov/content/pkg/FR-2020-06-02/pdf/2020-11969.pdf)
Effective Dates

Changes to 47 CFR 1.1310 went into effect June 1, 2020
- Removes certain limitations on permitted computational methods

Changes to 47 CFR 1.1307, 2.1091, and 2.1093 are not yet effective
- The process has started to establish an effective date
- We will announce the effective date with a Federal Register publication
Compliance Overview

**Low Power and/or Large Distance**

**Exemption**
Simple calculation to establish whether further compliance determination is necessary.

**Evaluation**
Determination of potential exposure levels to ensure compliance by measurement, calculation, or computational modeling.

**Mitigation**
Post-evaluation procedures to ensure that the exposure limits are not exceeded.

**Notice**

**CAUTION**

**Increasing Exposure**

**High Power and/or Small Distance**
New Exemption Criteria

- Replacing the service-specific exemption criteria with new, streamlined criteria

An RF source is exempt if it meets any of these exemption criteria, regardless of its radio service or classification as fixed, mobile, or portable:

- 1-mW blanket exemption
- Exemption formulas derived from limits on SAR
  - Available for separation distances 0.5 cm to 40 cm, and frequencies 0.3 GHz to 6 GHz
- Exemption formulas derived from limits on MPE
  - Available for separation distances $\geq \lambda/2\pi$, and frequencies 0.3 MHz to 100 GHz

The exemption formulas are available in the supplementary slides, and in amended 47 CFR 1.1307, 2.1091, and 2.1093
Changes to Evaluation

Numerical computation of SAR
- Allow use of any valid computational method
- Must be supported by adequate documentation showing full validation, and performed according to FCC-accepted standards or procedures (47 CFR 1.1310(d)(1))

Remove the 5 cm minimum evaluation distance for frequencies above 6 GHz (47 CFR 2.1093)
Changes to Mitigation

- Establish more specific mitigation measures for transmitter sites where RF exposure limits may be exceeded
  - Four exposure categories reflect potential RF exposure scenarios analogous to those of IEEE Std. C95.7-2014
  - Access control, signage, training requirements
  - See supplementary slides and amended 47 CFR 1.1307(b)(4)
FCC 19-126 Other Actions

Resolution of Notice of Inquiry
- Continues existing:
  - SAR and MPE limits, including as pertaining to children
  - SAR evaluation basic procedures, including test separation distance requirements
  - RF exposure information dissemination processes

Memorandum Opinion and Order
- Dismiss petition-for-reconsideration (DOC-322492; Public Notice Report No. 2988; 78 FR 52893; Aug. 27, 2013) thus affirm prior decision that pinnae (outer ears) are subject to extremity SAR limits

Notice of Proposed Rulemaking
- Comment and reply comments have been collected and are under review
Expected Guidance
Document Updates

- Public Notice
  - Clarify effective dates and transition period

- OET Bulletin 65
  - Revise main bulletin to include guidance for recent rule changes
  - Update supplements

- Small Entity Compliance Guide

- KDB Updates
Thank you
Supplementary Material
SAR-Based Exemption

Exempt if the greater of available maximum time-averaged power or ERP does not exceed $P_{th}$

Formulas in amended 47 CFR 1.1307, 2.1091 and 2.1093

$$P_{th} (\text{mW}) = \begin{cases} ERP_{20\text{cm}} (d/20 \text{ cm})^x & 0.5 \text{ cm} \leq d \leq 20 \text{ cm} \\ ERP_{20\text{cm}} & 20 \text{ cm} < d \leq 40 \text{ cm} \end{cases}$$

$$x = -\log_{10} \left( \frac{60}{ERP_{20\text{cm}} \sqrt{f}} \right)$$

$$ERP_{20\text{cm}} (\text{mW}) = \begin{cases} 2040f & 0.3 \text{ GHz} \leq f \leq 1.5 \text{ GHz} \\ 3060 & 1.5 \text{ GHz} < f \leq 6.0 \text{ GHz} \end{cases}$$

$$d = \text{separation distance (cm)}$$
MPE-Based Exemption

Exempt if ERP does not exceed the specified threshold
Separation distance (R) must be at least $\lambda/2\pi$
Formulas in amended 47 CFR 1.1307
Aligns with existing MPE limits under conservative exposure assumptions

<table>
<thead>
<tr>
<th>Transmitter Frequency (MHz)</th>
<th>Threshold ERP (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3 – 1.34</td>
<td>1,920 R²</td>
</tr>
<tr>
<td>1.34 – 30</td>
<td>3,450 R²/f²</td>
</tr>
<tr>
<td>30 – 300</td>
<td>3.83 R²</td>
</tr>
<tr>
<td>300 – 1,500</td>
<td>0.0128 R²f</td>
</tr>
<tr>
<td>1,500 – 100,000</td>
<td>19.2 R²</td>
</tr>
</tbody>
</table>

R = separation distance in meters
f = frequency in MHz
MPE-Based Exemption

- **2 kW ERP** @
  - 850 MHz: 13.6 m
  - 1900 MHz: 10.2 m

- **1 kW ERP** @
  - 850 MHz: 9.6 m
  - 1900 MHz: 7.2 m

- **100 W ERP** @
  - 100 MHz: 5.1 m
  - 850 MHz: 3 m
  - 1900 MHz: 2.3 m
Exposure Categories

NOTE: where potential for immediate and serious injury, regardless of category
Mitigation Measures

Category 2 (NOTICE):
- Signs, positive access controls (e.g., locked doors, ladder cages, fences, on-site building security)
- Appropriate training, supervision of transient persons

Category 3 (CAUTION):
- Signs, controls, indicators (e.g., chains, railings, contrasting paint, diagrams)
- Appropriate training, use of time-averaging or PPE

Category 4 (WARNING):
- Signs, restricted access (i.e., no transients), reduce power or lockout/tagout
Compatibility of Low-Frequency $E$-Field $ERL$s with $DRL$s

Rob Kavet
ICES SC3 Meeting
January 18-19, 2021
Background

- At low frequencies $E$-Field $ERL$s protect against:
  - Spark discharge at frequencies lower than the frequency at which the contact current $ERL$ is induced in a reference person;
  - Potentially adverse contact current at higher frequencies.
- Premise: Spark discharge and contact current thresholds at $E$-Fields that induce \textit{in situ} $E$-fields $<DRL$s.
- This premise re-visited here.
**E-Field Coupling Coefficients**

- Compared to *B*-Field modeling, limited amounts of data on *E*-Field coupling to tissue sites;
- CNS: Estimate 99\textsuperscript{th} percentile of $3.34 \times 10^{-2} \text{ (mV/m)/(kV/m-Hz)}$  
  - Dimbylow, 2005; Kavet et al, 2001 (from Stuchly group)
- Peripheral Nerve (PN): Estimate 99\textsuperscript{th} percentile of $0.583 \text{ (mV/m)/(kV/m-Hz)}$  
  - Dimbylow, 2005  
  - Based on skin and fat

➤ Compare induced *E*-Fields in CNS and PN at *ERL* to *DRL*  
  - UnRestricted and Restricted  
  - Repeat same for ICNIRP, 2010
IEEE Std C95.1-2019: UnRestricted CNS

![Graph showing E-Field ERL (kV/m), E(CNS), and DRL(CNS) vs. Frequency (Hz)]
IEEE Std C95.1-2019: UnRestricted PN

![Graph showing E-field ERL, E(PN), and DRL(PN) as a function of frequency (Hz). The graph includes a line indicating 240 Hz frequency and a dashed line representing the 99th percentile in situ E\textsubscript{PN} at E-ERL (V/m).]
ICNIRP, 2010: General Public, Head (CNS)
ICNIRP, 2010: General Public, Head & Body (PN)
ICNIRP, 2010: Occupational, Head (CNS)
ICNIRP, 2010: Occupational, Head & Body (PN)
Summary

- Based on very little dosimetry data,
  - For CNS, E-Field ERLs (IEEE) and RLs (ICNIRP), respectively, induce in situ electric fields lower than CNS DRLs and BRs for all tiers;
  - For peripheral nerve (PN), E-Field ERLs (IEEE) induce in situ electric fields greater than PN DRLs at >240 Hz (UnRestricted) and >180 Hz (Restricted);
  - For peripheral nerve (PN), E-Field RLs (ICNIRP) induce in situ electric fields lower than PN BRs (General Public and Occupational.)
Conclusions

• Before taking any action to revise the IEEE standard, further dosimetry for PN would be advisable (CNS as well);
• If the PN $DRL$ is exceeded by exposure to the $E$-Field $ERL$, then either,
  – The PN $DRL$ would need to be raised, or
  – The $E$-Field ERL would need to be lowered, or
  – A bit of both.

• Revisions to $E$-Field $ERL$s are impractical, because e.g.,
  – They are continuous with $E$-Field $ERL$s into RF frequencies;
  – Compliance in power line ROWs could become an issue;
  – $B$-Field compliance would require re-examination.
Final Comment

- The factors presented here might merit a peer-reviewed submission as a prelude to a revision of the standard;
- Personal opinion: PN DRLs have sufficient cushion in their safety factors to allow for a modest relaxation;
- First, however, corroborating dosimetry would be indispensable to initiating a revision to IEEE Std 95.1-2019, and hopefully…
- A laboratory with the appropriate expertise could be encouraged to conduct PN (and CNS) E-Field dosimetry.
Thank You!! Any Questions?
Lab Results that may be considered in future revisions

Alexandre Legros
Sebastien Villard, Nicolas Bouisset, Andres Carvallo
General context

Extremely Low Frequency Magnetic fields (ELF < 300 Hz)

Neurophysiological and/or behavioral effects? Thresholds?
Phase IV update (2017-2020)

1. **Frequency response** for *magnetophosphene* perception in humans – 1 to 300 Hz up to 100 mT

2. **Adaptation to the darkness** and threshold for *magnetophosphene* perception – 20 and 60 Hz up to 100 mT – 40 minutes adaptation

3. **Postural control** (sway) and vestibular MF exposure – 20, 60, 90, 120 and 160 Hz Electric (2mA) and MF (up to 100 mT) stimulations of 5 sec duration

3. **Subjective Visual Vertical** as an indicator of *vestibular performance* and MF exposure – 20, 60, 90, 120 and 160 Hz Electric (2mA) and MF (100 mT) stimulations of 25 sec
Magnetophosphenes: Thresholds for a stroboscopic visual perception triggered by alternating magnetic fields

\[ p = \frac{1}{1 + e^{(a + b \cdot \text{Flux Density})}} \]

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<tr>
<th></th>
<th>B</th>
<th>SE</th>
<th>Sig</th>
<th>Exp(B)</th>
<th>95% C.I. for EXP(B)</th>
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<td>20 Hz</td>
<td>Flux Density</td>
<td>0.134</td>
<td>0.008</td>
<td>&lt;.001</td>
<td>1.143 1.125 1.162</td>
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<td>Constant</td>
<td>-5.015</td>
<td>0.302</td>
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<td>0.164</td>
<td>0.009</td>
<td>&lt;.001</td>
<td>1.178 1.157 1.199</td>
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<td>Constant</td>
<td>-4.613</td>
<td>0.266</td>
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<td>60 Hz</td>
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<td>1.156 1.138 1.175</td>
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<td>100 Hz</td>
<td>Flux Density</td>
<td>0.082</td>
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<td>1.085 1.069 1.102</td>
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<td>Constant</td>
<td>-4.355</td>
<td>0.299</td>
<td>&lt;.001</td>
<td>0.013</td>
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\[ dB/dt = 2 \cdot \pi \cdot f \cdot B / 1000 \]
Frequency response of Magnetophosphene Perception during ELF MF exposure
In preparation

Extremely Low Frequency Magnetic Field Exposure and Associated Magnetophosphene Perception

In preparation

Extremely Low Frequency Magnetic Field Exposure and Associated Magnetophosphene Perception
- Which cells modulated?
- Action potential or graded potential cells?
- Possible extrapolation to the entire CNS?
- Adverse or non adverse effect?

**Implications from a standards perspective**

---

Retinal Imaging and Image Analysis
February 2010 · IEEE Reviews in Biomedical Engineering 3:169 - 208
DOI: 10.1109/BBME.2010.2084567
Source · IEEE Xplore

Michael Abramoff · Mona K Garvin · Milan Sonka
The vestibular system – Postural control and subjective visual vertical (SVV)

Thank you Nicolas for the vestibular slides!
Study I

Study II

Study III

The vestibular system – Postural control and subjective visual vertical (SVV)
Protocol

Human Postural Control Under High Levels of Extremely Low Frequency Magnetic Fields

NICOLAS BOUSSET\textsuperscript{1,2}, SÉBASTIEN VILLARD\textsuperscript{1,2}, AND ALEXANDRE LEGROS\textsuperscript{1,2,3,4,5}
Variables

Center Of Pressure
Results

- Positive control worked

- ELF-MF did not modulate postural control
Discussion

- Frequencies used

- Top down orientation of the fields

- Favored the otolithic subsystem

Attachment 9
Human Postural Control Under High Levels of Extremely Low Frequency Magnetic Fields

NICOLAS BOUISSET\textsuperscript{1,2}, SÉBASTIEN VILLARD\textsuperscript{1,2}, AND ALEXANDRE LEGROS\textsuperscript{1,2,3,4,5}
Impact of extremely low-frequency magnetic fields on human postural control

Sebastien Villard¹,2,3,4, Alicia Allen¹, Nicolas Bouisset³, Michael Corbacio¹, Alex Thomas¹, Michel Guerraz⁴, Alexandre Legros¹,2,3,5

Received: 15 June 2018 / Accepted: 21 November 2018
© Springer-Verlag GmbH Germany, part of Springer Nature 2018

Fig. 1 Exposure apparatus. Volunteer wearing the cap of the Starlab device used for DC- and AC-GVS (top left panel) and the helmet supporting the coils for MF exposure (top right panel).

Fig. 6 The path length, the area and the coronal velocity are lower when with the exposure helmet on the head as compared to standing without it. The standing balance is reduced by half or more (i.e., stabilization effect) with the helmet on.
Variables

Quantity of movement

\[ \rho \text{ (cm)} \]

Velocity (cm/s)

Quality of movement

Orientation of movement:

\[ \theta \text{ (degrees)} \]
Results

- Positive control worked

<table>
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<tr>
<th>Λ speed (cm/s)</th>
<th>CTRL</th>
<th>20 Hz</th>
<th>60 Hz</th>
<th>90 Hz</th>
<th>120 Hz</th>
<th>160 Hz</th>
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<td>AC</td>
<td>-0.30 ± 2.20</td>
<td>0.35 ± 1.81</td>
<td>-0.31 ± 1.69</td>
<td>0.42 ± 1.67</td>
<td>-0.13 ± 1.71</td>
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<td>MF</td>
<td>0.19 ± 1.72</td>
<td>0.45 ± 1.91</td>
<td>0.17 ± 1.85</td>
<td>-0.43 ± 1.59</td>
<td>-0.66 ± 1.32</td>
<td>0.07 ± 1.80</td>
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<th>ρ (cm)</th>
<th>AC</th>
<th>20 Hz</th>
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<td>AC</td>
<td>0.94 ± 0.59</td>
<td>0.99 ± 0.55</td>
<td>0.95 ± 0.60</td>
<td>1.13 ± 0.47</td>
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<tr>
<td>MF</td>
<td>0.96 ± 0.56</td>
<td>1.03 ± 0.70</td>
<td>0.83 ± 0.44</td>
<td>0.88 ± 0.50</td>
<td>0.93 ± 0.58</td>
<td>0.99 ± 0.60</td>
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- ELF-MF did not modulate postural control
Discussion - Frequency

Stimulation frequency matters

Up to 20 Hz

Filtering Mechanisms

Up to 300 Hz

Postural control

Forbes et al 2020
Dakin et al 2010
Discussion

POSTURAL CONTROL
Alternate approach?

Assess more directly vestibular activity

Filtering mechanisms

Utricular specific

Verticality perception

Mars et al, 2001
Volkening et al., 2014
Oppenländer et al., 2015
Jaeger et al 2008
Dalmaijer 2018
Vestibular alternating magnetic and electric stimulation effects on human subjective visual vertical perception.

Protocol

30s of stimulation for 4 stimulations
4 repetitions per stimulations

CTRL
DC 2mA
AC peak ± 2 mA
MF Constant dB/dt ~ 12.3 T.s⁻¹

20 – 60 – 120 – 160 Hz
The Subjective Visual Vertical (SVV) is a psychophysical measure of the angle between perceptual vertical and true (gravitational) vertical.


**Variables**

- Mean SVV value
- SVV Variability
- Time to adjust
Subjective Visual Vertical - SVV

Results

- No difference for the SVV value between MF and control or AC and control
General Discussion

- Postural Control
- SV

Limitations

- High Frequencies
- Most likely impact the utricles
- Both outcomes are highly integrated outcomes

Reynolds and Callum 2012
General Discussion – Perception

a Neural versus perceptual detection thresholds

- Regular
- Irregular
- VO (population of 12 neurons)
- Best regular
- VO (single)
- Human perception

Frequency (Hz)

Detection threshold (deg s⁻¹)

Less Integrated outcomes

More reflexive outcomes

Cullen 2019
Next Phase

Vestibulo-Ocular Reflex

Otero-Millan 2015
Mackenzie & Reynolds 2018
Now - Phase V (2020-2024): Laboratory Duplication and Experimental studies

Human Central and Peripheral Responses to MFs up to 100 mT at Power Frequencies – Visual, Vestibular, Somatosensory and Synaptic studies

- Nicolas – From PhD to Postdoc
- Lynn – Technical manager
- Jessica – 4th year project
- Elinor – 4th year project
- Frank – Department leader

- Andres – Postdoc
- Simon – Technical support
- Maorie – Masters 1 project
- Perrine – Engineer student (last year)
- Sofiane and Ludo – Univ Profs
- Stephane – Department leader
Phase V: Laboratory Duplication and Experimental studies

1. **Oculo-vestibular reflex and local MF exposure up to 100 mT** - Eye torsion under ELF-MF stimulation

2. **Threshold for Peripheral Nerve Stimulation (PNS)** - Threshold from ICNIRP and IEEE extrapolated at 50 and 60 Hz from higher freqs
   Aim: test the PNS threshold experimentally in humans at 50 - 60 Hz

3. **Replication magnetophosphene perception threshold in humans’ study**

4. **Threshold for a direct impact on brain networks and functions** - Working Memory and EEG tested under and after 50 and 60 Hz up to 100 mT. Synaptic modulations would be associated with modulation of memory performance
Phase V: Laboratory Duplication and Experimental studies - Montpellier
Lab duplication Montpellier

- Big coils – 100 mT

  - 2 x 99 turns of hollow copper wire
  - $1795 USD x 2 winding
  - $4200 USD of wire (200 pounds of wire @$21/lb) plus shipping
  - Development costs
  - Manufacturing costs
  - Certification costs
Lab duplication Montpellier

- Small Coils – 100 mT
  - 176 turns hollow copper wire
Lab duplication Montpellier

Lab Setup
- 100 mT RMS Magnetic Field
- Coil inductance = 5.6 mH

Recirculating Chiller

Gradient Amplifier

DAQ Card

PC

Coil & Lifter

Thank you Andres for the Montpellier lab and electrophosphenes slides!
### Active Ethics Canada (Western and Lawson)

#### Projects

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Phase V: Oculo-vestibular – eye torsion

Knowing what the brain is seeing in three dimensions: A novel, noninvasive, sensitive, accurate, and low-noise technique for measuring ocular torsion

Jorge Otero-Millan; Dale C. Roberts; Adrian Lasker; David S. Zee; Amir Kheradmand

Mackenzie & Reynolds 2018
Eye movements can indicate **activation of the vestibular system**

Well-established methods for measuring horizontal and vertical eye movements
- No standard technique for measuring torsion
- Method developed by Otero-Millan et al in 2015

**Needs**
- Develop a **program to measure eye movements in 3 dimensions**
- Observe **ocular torsion** due to **magnetic stimulation** of the vestibular system
Vestibular – eye torsion

Thank you Jessica for the eye torsion slides!
Vestibular – eye torsion

Original Image  Edge Image  Detected Lines

Attachment 9
Vestibular – eye torsion

Fitted Parabolas

Mask

Mask applied
Vestibular – eye torsion

Polar image  Low pass  Sobel
Iris pattern optimization

Resized to 360x60 pixels

Extended pattern by 25 pixels on each side -- 410x60 pixels
Status

- Torsion calculation
  - Template matching
  - Subpixel resolution
- Geometric correction
- Measuring torsion
Phase V: PNS Threshold

Median PNS threshold of 47.9 T/s peak for a coronal body exposure at 60 Hz

Uncertainty due to extrapolation (threshold between 2.07 and 6.5 V/m depending on the studies and methods)
A  Leg Solenoid - Simulation Se

Single-Layer MPI Solenoid

E-Field [mV/m/A]

C  Arm Solenoid - Simulation Sc

Double-Layer MPI Solenoid

E-Field [mV/m/A]
Phase V: Electrophosphenes – Pilot prior to study duplication

- Ethic approval
- Creation of setup and stimulation protocols
- Volunteers recruitment (N = 11 volunteers tested, goal N=20)
Electrophosphenes – Pilot prior to study duplication

Preliminary Results:
- 1 Volunteer
- $f = 20$ Hz
- $I_{\text{stim}} = 0 - 1.5$ mA (0.15 mA step)

Threshold @50% = 0.49 mA
Frequency-Dependent and Montage-Based Differences in Phosphene Perception Thresholds Via Transcranial Alternating Current Stimulation

Ian D. Evans, Stephen Palmisano, Sarah P. Loughran, Alexandre Legros, and Rodney J. Croft

Fig. 2. Individual thresholds for transcranial alternating current stimulation (tACS)-induced phosphenes for our 24 participants using either an FPz-Cz (a) or an Oz-Cz (b) montage, as a function of stimulation frequency.

Fig. 5. Individual regression curve estimates of phosphene perception thresholds as a function of frequency for each of the 24 participants.
Next

- Finish Electrophosphenes studies
  - 17 volunteers tested (20 volunteers on total)
  - Analysis and scientific report

- Install the Magnetic Stimulation system
  - Validation and testing equipements

- Future experimentation
  - Pupil dilatation
  - EEG analysis
  - Memory experimentation

- Dosimetry modelisation
  - Anatomical structure

- Synaptic plasticity models
  - LTP and Memory

[Tonnesen et al, 2014]
Phase V: Threshold for a direct impact on brain networks and functions

Fast rhythm (gamma)
Slow rhythm (theta)

- Current results suggest that we can remember as many items as the number of gamma oscillations per cycle! What happens if the brain is stimulated at those frequencies?
Threshold for a direct impact on brain networks and functions

Current Biology
Spatial Working Memory in Humans Depends on Theta and High Gamma Synchronization in the Prefrontal Cortex

Authors
Ivan Alekseichuk, Zoë Turl, Gabriel Amador de Lara, Andrea Antal, Walter Paulus

Correspondence
ivan.alekseichuk@med.uni-goettingen.de

In Brief
Alekseichuk et al. demonstrate the role of theta-gamma cross-frequency coupling in human prefrontal cortex for working memory by using causal inference. They applied cross-frequency transcranial alternating current stimulation and showed the phase and frequency specificity of theta-gamma rhythms during working memory performance.

WM Performance, EEG source reconstruction and connectivity

Working Memory task and EEG
Threshold for a direct impact on brain networks and functions - ANR

LOI due December 1st

NeuroSTIMulation of brain NETworks (STIMNET)

Julien MODOLO & Alexandre LEGROS

Accepted to collaborate:
Nir Grossman’s team – Imperial College, London, UK
Niels Kusters’s team – IT IS Zurich, Switzerland
Threshold for a direct impact on brain networks and functions - ANR

- Identify the **effects of electric / magnetic / TI stimulations on brain functional networks and task performance** in humans.

Three experimental tasks. Each performed a different day.

- Task 1: resting state
- Task 2: motor task (Fitt’s task)
- Task 3: cognitive task (Simon task)

tACS / MF / TI stimulations sham first or real first

---

IEEE ICES 2021
SC3-4 meeting
January 19th 2021
Summary – Phase V: 2020 - 2024

- Magnetophosphenes publications on their way - Team priority – targeting contributing to Guideline/Standards evolutions (thresholds and mechanisms)

- ELF vestibular effects up to 100 mT will have been thoroughly investigated – Eye torsion study ready to start (Phase V)

- Steps towards magnetophosphenes replication initiated (pilot study half-way and new lab in place end of the spring) – data acquisition starts in the fall 2021

- CNS effects - WM and EEG testing synaptic modulations - will address both Guidelines/Standards and application perspectives

- PNS threshold will be the first at 50-60 Hz and will address a Guidelines/Standards gap – plan to start pilot data collection in the fall 2021 (PhD student recruitment planned)

- Involvement helping to shaping the next steps in LF Standards and Guidelines
Impact on Standards and Guidelines

International Committee on Electromagnetic Safety
Institute of Electrical and Electronics Engineers
Piscataway, NJ, USA

VIRTUAL GLORE 2020 MEETING
November 9, 2020
IEEE-ICES - LF priorities

- **CNS effects**
  - Transition from *magnetophosphene*es to *transcranial* magnetic/electric stimulation?
  - Goal: *Dose*- and *Frequency-Response* characteristics (not trivial)
  - Initial *formulation of working group*

- **Incorporate anatomical modeling** into determining *effect thresholds* and ERLs
  - **CNS**/Small neurons
  - **PNS**/Peripheral nerve stimulation
  - **Heart** (not critical at this time – higher stimulation threshold)
Neural network firing patterns. The EHC Monograph stated: “A lower bound of 1 mV m\(^{-1}\) on neural network discrimination was suggested, but based on current evidence threshold values around 10-100 mV m\(^{-1}\) seem more likely”

tive resolution]. The phenomenon of magnetophosphenes, which are thought to arise from magnetic induction of electric fields in the neural networks of the retina, continues to be studied experimentally (Legros et al. 2012; ) and theoretically (Laakso and Hirata 2012a and b). However, the

Dosimetry and modeling

The estimate of the threshold in terms of the internal electric field strength for neural stimulation effects in the retina (between 50 and 100 mV m\(^{-1}\)) could usefully be clarified. Since the basic restriction for the central nervous system
**C95.1 – what’s next**

- **Validity period of 10 years** from the date of IEEE-SA Standards Board approval
  - At the end of 10 years, the standard must be revised, withdrawn, or become inactive
  - Amendments and corrigenda do not affect this validity period

<table>
<thead>
<tr>
<th>Year</th>
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<tr>
<td>2019</td>
<td>Publish C95.1-2019 and Corrigenda</td>
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<tr>
<td>2020</td>
<td>Establish initial task forces and plan for ongoing literature review</td>
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<tr>
<td>2021</td>
<td>Publish amendment to low frequency limits</td>
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<td>2022</td>
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<td>2023</td>
<td>Submit Project Authorization Request (PAR) and establish Editorial Working Group</td>
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<td>2026</td>
<td>Cut-off date for publications to be included in literature review</td>
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<tr>
<td>2027</td>
<td>First draft of revised C95.1</td>
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<td>2028</td>
<td>Internal review</td>
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<td>2029</td>
<td>Legal, style, formatting reviews</td>
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<td></td>
<td>Balloting and recirculation balloting, including public review</td>
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<td>Publish C95.1-2029</td>
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Thank you!

International Committee on Electromagnetic Safety
Institute of Electrical and Electronics Engineers
Piscataway, NJ, USA