1. **Call to order**

   The meeting was called to order at 9:10 AM on 23 January 2018 by SC4 co-chair Marv Ziskin in Chandler, AZ.

2. **Introduction of those Present**

   Each of the attendees introduced her/himself. *(Attachment 1.)*

3. **Approval of Agenda**

   The agenda is modified as follows: Secretary’s report is to be postponed until tomorrow to be presented during TC95 Committee Meeting. A presentation by Antonio Faraone will be added to the agenda during the progress report on revision of PC95.1-2005. Following a motion by Ric Tell that was seconded by Jim Hatfield, the agenda was approved as modified. *(Attachment 2.)*

4. **Approval of the January 2016 SC3/4 meeting minutes**

   Following a motion by Marv Ziskin that was seconded by C-K Chou, the August 2017 SC3/4 meeting minutes were approved with no modifications.

5. **Call for Patents**

   There was a call for patents and no responses.
6. Secretary’s Reports

Postponed until tomorrow to be presented during the TC95 Committee meeting.

7. Chairmen’s Reports

Marv Ziskin presented the Chairmen’s Reports for SC3/4 (Attachment 3), including the main goals and active tasks of SC3/4. He reviewed the ongoing revision and merging of IEEE Stds C95.1-2005 and C95.6-2002. Special thanks is offered to individuals for their efforts on the C95 revision, including Antonio Faraone, C-K Chou and Ron Petersen. There is increased collaboration between ICES, WHO and ICNIRP. ICNIRP invited comments from ICES on revisions to their guidelines and is taking time to address those comments. Congratulations is offered to Akimasa Hirata, who was recently awarded the 2018 Japan Academy Medal for numerical analysis physics, thermodynamics and neurophysiology, and for the application to EMF safety, thermal safety and medicine.

Rob Kavet commented that contemporary dosimetry must become the gold standard for establishing our DRLs, utilizing the results being generated by SC6. He noted that this should be a focus of our work this year.

8. Organization and Process for Revising C95.6-2002

a. Task Force 1: Report on CNS effects and limits

Alexandre Legros presented “TF-1 Report- CNS Magnetic Field Exposure Limit – LF” (Attachment 4). The objective of this task force is the revision of CNS limits currently based on phosphenes, and to provide recommendations for DRLs and ERLs to be incorporated into draft standard due this year. The short deadline for C95.1 revision precludes adequate literature review, so the task force has adapted their strategy to keep phosphenes as the basis for the ongoing C95.1 revision, and to undertake a longer-term review for future revisions. Legros recapped their November TF-1 report, summarizing their working assumptions, including phosphene synapse modulation mechanisms specific to the retina and CNS effects at levels below demonstrable neuro-excitation. Legros stated that further work leading to CNS limits should focus on reviewing literature for transcranial electro- and magneto- stimulation. He noted that recent large sample human data suggests threshold levels at 20 Hz 2 to 4 times greater than those of Løvsund et al. (1979) which currently form the basis for limits in C95.6. Legros reviewed specific details for how to address DRLs and ERLs in the ongoing C95 revision, and then highlighted topics that should be covered over the year 2018 for the longer-term review, including reconsidering phosphenes as the basis for limits. Legros underscored that this work will require a long-term comprehensive review: any substantial change will require strong evidence in support of such change. He then highlighted several studies that serve as a starting point for the longer-term CNS literature review.

b. Task Force 2: Report on PNS effects and limits

This presentation was delivered after C-K’s “IEEE ICES Standards Update” below.
Akimasa Hirata presented “Revisit of Relationship between Permissible Magnetic Field Strength and In-situ Electric Field Prescribed in the IEEE C95.6 Standard” (Attachment 5). C95.1 utilized anatomical models for deriving relationship between internal and external field strengths, but ellipsoidal models were used for C95.6. This task force intends to apply anatomical models for these lower frequencies covered by C95.6. The task force has compared anatomical modeling results gathered from several different researchers. Akimasa summarized that, in these preliminary modeling results, the calculated in-situ electric fields in the brain exceeded the Basic Restriction, good agreement was obtained in the in-situ electric field in parts excluding limbs, and the classification of the limbs differed between researchers involved in this study.

9. Progress on Revision of PC95.1-2005
   a. IEEE ICES Standards Update

C-K Chou presented “IEEE ICES Standards Update” (Attachment 6) reviewing the IEEE ICES organization, TC34 standards, and TC95 standards. ICES is SCC-39 within IEEE, TC34 covers product standards, and TC95 covers exposure standards. C-K reviewed the TC34 measurement standards, and the dual efforts from IEEE/IEC on 5G mmWave standards and computational modeling standards. He then provided a timeline for IEEE exposure standards and expiration dates, a list of ICES standards available for free, and the status of ICES TC95 standards. The remainder of the presentation focused on status of the C95.1 revision, and the merging of C95.1 and C95.6. For literature review, an extensive research database is maintained by Joe Elder and accessible online at http://ieee-emf.com/. C-K highlights that ICES is committed to the development of a science-based RF safety standard that is protective of public health, unambiguous, and practical to implement. ICES also desires for this standard to be harmonized with international limits. C-K then reviewed certain terminology that is being clarified in the C95.1 revision, including the replacement of “Basic Restriction (BR)” with “Dosimetric Reference Level (DRL),” the replacement of “Maximum Permissible Exposure (MPE)” with “Exposure Reference Level (ERL),” and the use of terminology related to restricted environments. C-K then overviewed the main strategies or changes to DRLs and ERLs in the C95.1 revision for below 100 kHz, 100 kHz to 6 GHz, and above 6 GHz, with much of this discussion focusing on revisions above 6 GHz.

b. Mobile & Wireless Forum (MWF) Comments on the Proposed Limits Above 6 GHz

C-K Chou presented comments from MWF on the proposed C95.1 limits above 6 GHz (Attachment 7). These were further discussed by Antonio below.

c. Further Comments from the MWF on the Proposed Limits Above 6 GHz

Antonio Faraone presented “Further Comments on the IEEE C95.1 Revision” from the MWF (Attachment 8). Main comments from MWF pertained to the penetrating power density (PPD) metric and a potential discontinuity at the transition from specific absorption rate to power density, commented that the change in averaging area at 30 GHz does not seem justified, and suggested introducing revised PPD limits for extremities. They further commented that the same limits intended to be averaged over a small area should be applicable to prevent whole-body heat stress.
and suggested the inclusion of a general statement that compliance with incident power density limits are sufficient to show compliance with the standard. The presentation then included an analysis of potential implications of the standard on product maximum power levels.

Akimasa Hirata and C-K Chou responded with justification of currently selected averaging areas and frequency breaks for the proposed limits above 6 GHz, acknowledging that there should be an effort to make the limits practical for implementation. C-K commented that this will be considered in our working group meeting for revision of these limits. William Bailey commented that the averaging areas are not currently based on biological effects. Jerrold Bushberg inquired on the coverage of multi-frequency exposure combining surface and deeper heating; C-K Chou and Richard Tell noted multi-frequency exposure is covered in the standard, but this specific scenario may not be directly detailed. Robert Cleveland inquired on the presence of a transition region between 3 GHz and 6 GHz; C-K Chou responded that such a transition is not currently present or needed in the proposed limits.

d. NEMA Web Resources for Involvement with IEC Technical Committees

Ken Gettman presented websites for involvement with IEC technical committees. Ken recommends contacting him if you have any questions or are interested in becoming a Technical Advisory Group (TAG) member to participate in these IEC activities.

https://workspaces.nema.org facilitates involvement with IEC technical committees, including the IEC TC106 committee and efforts pertaining to IEEE TC34. Ken highlighted a calendar of upcoming meetings and events, documents for review, and the option to submit comments.

https://standards.nema.org is used for balloting. This website provides access to view, comment, and vote on IEC documents.

e. IEEE ICES Electromagnetic Field Literature Database

Marv Ziskin presented a brief status update on behalf of Joe Elder concerning the extensive research database accessible online at http://ieee-emf.com/ (Attachment 9). This database contains several thousand EMF references, primarily concerning the RF range.

f. IEEE ICES TC95 Literature Review Update

Antonio Faraone presented a status update on the IEEE ICES TC95 literature review. Topic groups were identified based on Annex B of C95.1-2005 and more than 50 volunteers were organized to undertake review of each topic for contribution to the C95.1 revision. Contributions to the ongoing C95.1 revision focus on frequencies above 6 GHz. Findings from this literature review contributed to Annex C in the revised C95.1, with review of select topics still ongoing. Richard Tell has been working on incorporating these references and citations into the C95.1 revision.
10. Other New Business

There was a call for new business with no responses.

11. Date and Place of Next Meeting

The next SC3/4 meeting will take place on 14 August 2018 in Eureka Springs, Arkansas.

12. Adjourn

Motion to adjourn by Ray Harmon at 1:40 PM, seconded by Jim Hatfield.
List of Attendees
IEEE/ICES TC95 Subcommittee 3 and Subcommittee 4 Meeting
Chandler Community Center, Chandler, AZ, 85225
0900 – 1530 h
Tuesday, 23 January 2018

<table>
<thead>
<tr>
<th>Last Name</th>
<th>First Name</th>
<th>Affiliation</th>
<th>Country</th>
<th>IEEE-SA Member?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bailey</td>
<td>Bill</td>
<td>Exponent</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Bender</td>
<td>Klaus</td>
<td>Site Safe LLC</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Bodemann</td>
<td>Ralf</td>
<td>Siemens</td>
<td>DE</td>
<td>Y</td>
</tr>
<tr>
<td>Bushberg</td>
<td>Jerrold</td>
<td>U C Davis School of Medicine</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Chou</td>
<td>C-K</td>
<td>Chou Consulting</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Cleveland</td>
<td>Robert</td>
<td>EMF Consulting</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>De Santis</td>
<td>Valerio</td>
<td>University of L'Aquila</td>
<td>IT</td>
<td>Y</td>
</tr>
<tr>
<td>Doczkat</td>
<td>Martin</td>
<td>FCC</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Faraone</td>
<td>Antonio</td>
<td>Motorola Solutions, Inc.</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Fisher</td>
<td>Kevin</td>
<td>Smith and Fisher LLC</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Gettman</td>
<td>Ken</td>
<td>NEMA</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Glembo</td>
<td>Tyler</td>
<td>Intel</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Graf</td>
<td>Kevin</td>
<td>Exponent</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Haes</td>
<td>Donald</td>
<td>BAE Systems</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Harmon</td>
<td>Ray</td>
<td>URS Corporation</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Hatfield</td>
<td>Jim</td>
<td>Hatfield and Dawson</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Hirata</td>
<td>Aki</td>
<td>Nagoya Institute of Technology</td>
<td>JP</td>
<td>Y</td>
</tr>
<tr>
<td>Johnson</td>
<td>Robert</td>
<td>Unaffiliated</td>
<td>US</td>
<td></td>
</tr>
<tr>
<td>Kavet</td>
<td>Rob</td>
<td>Kavet Consulting LLC</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Kihlstrom</td>
<td>Cory</td>
<td>Verizon</td>
<td>US</td>
<td></td>
</tr>
<tr>
<td>Kim</td>
<td>Soo</td>
<td>IEEE SA</td>
<td>US</td>
<td></td>
</tr>
<tr>
<td>Legros</td>
<td>Alexandre</td>
<td>Lawson Health Research Institute</td>
<td>CA</td>
<td>Y</td>
</tr>
<tr>
<td>Last Name</td>
<td>First Name</td>
<td>Affiliation</td>
<td>Country</td>
<td>IEEE-SA Member?</td>
</tr>
<tr>
<td>-----------</td>
<td>------------</td>
<td>-------------</td>
<td>---------</td>
<td>----------------</td>
</tr>
<tr>
<td>Maxson</td>
<td>David</td>
<td>Isotrope</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Miyagi</td>
<td>Hiroaki</td>
<td>HM Research &amp; Consulting Co., Ltd.</td>
<td>JP</td>
<td>Y</td>
</tr>
<tr>
<td>Santulli</td>
<td>Jen</td>
<td>IEEE SA</td>
<td>US</td>
<td></td>
</tr>
<tr>
<td>Stollar</td>
<td>Christopher</td>
<td>Dtech Communications</td>
<td>US</td>
<td></td>
</tr>
<tr>
<td>Tech</td>
<td>Darang</td>
<td>Dtech Communications</td>
<td>US</td>
<td></td>
</tr>
<tr>
<td>Tell</td>
<td>Ric</td>
<td>Richard Tell Associates, Inc</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Visser</td>
<td>Auke</td>
<td>Royal Netherlands Navy</td>
<td>NL</td>
<td>Y</td>
</tr>
<tr>
<td>Weller</td>
<td>Robert</td>
<td>National Broadcasting Association</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Wessel</td>
<td>Marv</td>
<td>Global RF Solutions</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Young</td>
<td>Roger</td>
<td>Unaffiliated</td>
<td>US</td>
<td>Y</td>
</tr>
<tr>
<td>Ziskin</td>
<td>Marvin</td>
<td>Temple University</td>
<td>US</td>
<td>Y</td>
</tr>
</tbody>
</table>
International Committee on Electromagnetic Safety

Draft 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

0900 – 1530 h
Tuesday, 23 January 2018

Chandler Community Center
125 East Commonwealth Avenue,
Chandler, AZ, 85225

1. Call to Order
Ziskin

2. Introduction of those Present
All

3. Approval of Agenda
Ziskin

4. Approval of the Minutes (11 January 2017 Meeting)
Ziskin

5. Secretary's Report
Petersen

6. Chairmen's Reports
SC3/SC4 Co-chairs

7. Organization and Process for Revising C95.6-2002
Reilly

   a) Task Force 1: Report on CNS effects and limits
Legros/Modolo

   b) Task Force 2: Report on PNS effects and limits
TBD

8. Progress on Revision of PC95.1-2005
Ziskin

   a) Update on STANAG 2345 status
Klauenberg

   b) Update on the revision of C95.1-2005 and C95.6-2002
Chou

   c) ELF/RF Literature surveillance
Elder

   d) ELF/RF Literature review
Group Leaders

   e) Update on the revision of ICNIRP guidelines on HF fields
Chou/Hirata

   f) Update on the WHO International EMF Project (EHC on RF fields)
TBD

9. Technical Presentations
TBD

   a) TBA
TBD

   b) TBA
TBD

10. Other New Business
Ziskin

11. Date and Place of Next Meeting
Ziskin

12. Adjourn
Chairman’s Report

SC – 3 & 4

January 23, 2018
Chandler, Arizona
SC – 3: Safety Levels 0 Hz to 3 KHz

Co-Chairs: Rob Kavet
          Kevin Graf

SC - 4: Safety Levels 3 KHz to 300 GHz

Co-Chairs: Art Thansandote
           Marv Ziskin
Major Task of SC – 3/4

Ongoing Revision of
C95.1-2005   RF Safety Standard (3 kHz – 300 GHz)
to incorporate
C95.6-2002   LF Safety Standard (0 Hz – 3 KHz).

Goal:   December 31, 2018

C95.1-2018   Safety Standard (0 Hz – 300 GHz)
Progress on Standards
Editorial Working Group (EWG)

- Bill Bailey
- Ralf Bodemann
- Bob Cleveland
- C-K Chou
- Antonio Faraone
- Ken Foster
- Ken Gettman
- Kevin Graf
- Aki Hirata

- Rob Kavet
- Alex Legros
- John Opsepchuk
- B Jon Klauenberg
- Ron Petersen
- Pat Reilly
- Ric Tell
- Art Thansandote
- Marv Ziskin
Progress on Standards
Editorial Working Group (EWG)

Frequent Teleconferences
Monthly at First, then Weekly

Face to Face Meetings
2 Days in August and in December

Occasional Special Topic Teleconferences
Safety Issues

Special Thanks to Antonio Faraone
Progress on Standards
Editorial Working Group (EWG)

Special Task Groups

1. Introduction
2. Above 6 GHz Power Density Limits
3. Spatial Averaging over the Body
4. Averaging Time – Environments
5. Averaging Time – Whole Body and Localized
6. Coverage of C95.6
7. Definitions
8. Annex A, B, C, and D
Progress on Standards

Special Thanks to two individuals:

C-K Chou
Lead the work on the revision

Ron Petersen
Master Scribe
Progress on Standards

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

http://standards.ieee.org/about/get/index.html

Thanks to

US Air Force,
US Army
US Navy

Free downloads will be extended for another 5 years, thanks to B. Jon Klauenberg
ICES Data Base and Literature Review

Data Base & Literature Surveillance
Joe Elder

Literature Review
Antonio Faraone, Chair
Interaction with World Health Organization (WHO)

In response to C-K Chou,

WHO has agreed to encourage international harmonization of RF Safety Limits,

especially between ICNIRP and ICES
Interaction with International Commission on Non-Ionizing Radiation Protection (ICNIRP)

Proposed new approach and limits for RF exposures

Invited comments from ICES

ICNIRP has delayed finalizing their conclusions to give full consideration of ICES’s recommendations

Rodney Croft, Ph.D.:
Presentation and Interaction with EWG
Akimasa Hirata, Ph.D.

Awarded 2018 Japan Academy Medal

For:
1. Numerical analysis of physics, thermodynamics and neurophysiology
2. Application to EMF safety, thermal safety, and medicine

Consequences:
1. Researcher for heat stroke management in Japan
2. His computations will be used in summer events, such as Olympic Game (2020)
3. Appeared on TV ~100 times
4. Appeared in newspapers > 1000 times
Akimasa Hirata, Ph.D.

2018 Japan Academy Medal Awards

2 Awards for Humanities and Economics
2 Awards for Biology and Medicine
2 Awards for Physics, Chemistry, and Information Science

Aki is the first Electrical Engineering Awardee
IEEE-ICES TC95 Winter Meeting

TF-1 report – CNS Magnetic Field Exposure Limits - LF

Chandler Community Center
Chandler, Arizona
22–24 January 2018
C95.6 – Phosphenes and CNS implications task force

• Objective: Revision of CNS limits currently based on phosphenes - Provide recommendations for DRLs and ERLs to be incorporated into draft standard due this year – Central Nervous System (CNS)

• TF-1 current members:
  • Bill Bailey
  • Aki Hirata
  • Ilkka Laakso
  • Julien Modolo
  • Alex Legros (lead)

• Coordinators and reviewers:
  • JP Reilly
  • Rob Kavet
Considerations for revision of CNS limits: Challenges faced in the process

- Getting to actually know the content of the guidelines – learning curve

- Technical difficulties – impossibility to open the IEEE doc with Word on Mac

- Underestimated the time commitment required → Not able to keep up with new draft versions and volume of peripheral working memos associated

Lessons learned:

- Better prioritize - not being overwhelmed by the material

- Adapt to the workflow – do “less but often” instead of trying a lot on one time

- Better use of the WG members and their expertise

- Explore the possibility of using an online shared document platform like Drop Box or googledoc -
  [https://docs.google.com/document/d/1Lwv551VslmC24BQBcBU-H850GINxCUqWviREe6gVPUM/edit](https://docs.google.com/document/d/1Lwv551VslmC24BQBcBU-H850GINxCUqWviREe6gVPUM/edit)
Considerations for revision of CNS limits: Central Nervous System - CNS

Currently:

- Experimental data on phosphenes are a foundation for CNS dosimetric reference limits (DRLs)

- Phosphenes are not considered per se adverse

- The adverse effect for CNS exposure noted in C95.6 is “headaches and nausea or indisposition” as reported by Lövsund et al. (1980a, 1980b) and Silny, (1986)

- The mechanism of electro- and magneto-phosphenes is understood to involve interactions from induced E-fields with synaptic junctions in the retina. Similar mechanisms are presumed to be involved at synaptic junctions in the brain. The associated adverse effects is assumed to be a result of modification of synaptic activity in the cortex

- The minimum thresholds at optimum frequencies for phosphenes are 50 – 100 times lower than that for excitation of PNS neurons
Working assumptions for CNS revision – TF-1 November report

- Phosphene synapse modulation = mechanisms specific to the retina (graded potential neurons and ribbon synapses) and not corresponding similar effects in the cortex of the brain - structural and functional differences – dose and frequency responses specific to phosphenes (e.g. almost no phosphene perception above 100 Hz)

- Outside of phosphene data, experimental evidence shows CNS effects from electro-stimulation on the brain at levels well below demonstrable neuro-excitation in situ thresholds (e.g., 10 V/m pk vs. 0.075 V/m, pk, which corresponds to the retinal phosphene thresholds)

- Further work leading to CNS limits should focus on reviewing the literature concerning transcranial electro- and magneto-stimulation. This coverage should include low-level in-vivo and in-vitro exposure of human and animal subjects/preparations, including tDCS and tACS experimental and clinical studies (healthy volunteers and patients)

- The short deadline for editing C95.1 precludes adequate review of this literature

- Therefore, hold CNS revision of C95.1 for implementation, and a longer-term review and development during 2018, with the objective of a more comprehensive CNS revision during 2019
IEEE limits currently based on **8.14 mT RMS median 20-Hz magnetophosphene threshold** in Lövsund et al, 1979 - higher thresholds in other experiments from this group (Lövsund et al., 1979, 1980a and b)

Recent large sample human data from the Lawson Group exhibits maximum sensitivity at 20 Hz, compared to 50, 60 and 100 Hz, although lower frequencies are untested yet. However, threshold at 20 Hz 2-4 times greater compared to Lövsund

95.6 adopted Lövsund et al., threshold as also *representative of brain synapse* (after effects) using electrostimulation model
Considerations for revision of CNS limits:
Recommendation for the draft

- **Elliptical uniform conductivity (EUC)** in 95.6 used an ‘anatomic’ location within the ellipsoid intended to correspond to the site of synaptic activation in the CNS

- In 95.6: 20-Hz field (corner frequency $f_e$) of $8.14 \text{ mT}_{\text{RMS}}$ produced $53.0 \text{ mV/m}$ at target site
  
  -> DRL UT = $17.7 \text{ mV/m}$ and DRL LT = $5.89 \text{ mV/m}$ (all RMS) - for $f \leq f_e$ (20 Hz);
  
  -> DRLs increased by $f/f_e$ for frequencies $>20 \text{ Hz}$

- Keep corner frequency, $f_e=20 \text{ Hz}$

- Keep UT and LT ERLs of $2.71 \text{ mT}$ and $0.904 \text{ mT}$ for $f>f_e$ until intersecting with the PNS limit, then **ERLs increase by $f_e/f$ for frequencies $\leq 20 \text{ Hz}$ and $>0.153 \text{ Hz}$**

- DRLs are derived using TF-2 CNS coupling factor from anatomical models
Considerations for revision of CNS limits: Long term recommendation (over the year 2018)

- Reconsider phosphenes as a basis for CNS limits in C95.1:
  - Differences between retinal vs. brain neuro-modulation mechanisms - rationale describing the neurophysiological retinal specificities (in structure and function)
  - Reconsider whether phosphenes per se are adverse, and whether other possibly adverse reactions during phosphene experiments are credible (e.g., as suggested by Lövsund and Silny)

- Further efforts to revise CNS limits should focus on the brain itself whether or not phosphenes are kept as the most sensitive basis for setting limits - Review should be addressed by a continuation of TF-1 (tDCS/tACS literature), additional membership as needed – Pat contacts Marom Bikson

- A working definition of “adverse reaction” with respect to CNS exposure is needed. A conservative definition might include any demonstrable CNS effect firmly established in-vivo (especially in humans). A more focused definition of “adverse reaction” for CNS reactions should also be considered
Considerations for revision of CNS limits: Long term recommendation (over the year 2018)

- Further development of CNS limits might result in substantial changes in C95.1 – possibly involving an increase in the limits. This requires a long-term comprehensive review: any substantial change will require strong evidence in support of such change.

- **Rheobase** and **corner frequency** parameters need to be derived from the literature review of experimental CNS electrostimulation studies. This might include reconsideration of the studies mentioned in the present standard, as well as studies not included in the C95.6-2002 Standard – define **neurostimulation** and **neuromodulation**.

- This thorough review process (over the year 2018) needs to allow to redefine DRLs and ERL for consideration in an updated revision.
CNS literature review:
Starting point

- Experiments
- Dosimetry
- Modeling

Work for the WG1 – SC6

- Local field potentials (LFPs) and multiunit activity (MUA) – stim .05 V/m
Injecting Instructions into Premotor Cortex

Kevin A. Mazurek, and Marc H. Schieber

Noninvasive Deep Brain Stimulation via Temporally Interfering Electric Fields

Nir Grossman, David Bono, Nina Dedic, Suhasa B. Kodandaramaiah, Andrii Rudenko, Ho-Jun Suk, Antonino M. Cassara, Eras Neufeld, Niels Kuster, Li-Huei Tsai, Alvaro Pascual-Leone, and Edward S. Boyden

Oscillatory Dynamics in the Frontoparietal Attention Network during Sustained Attention in the Ferret

Kristin K. Sellors, Chunxiu Yu, Zhe Charles Zhou, Iain Stitt, Yuhui Li, Susanne Radtke-Schullier, Sankaraieengam Alagapan, and Flavio Fröhlich

Low-Intensity Electrical Stimulation Affects Network Dynamics by Modulating Population Rate and Spike Timing

Davide Reato, Asif Rahman, Marom Bikson, and Lucas C. Parra
CNS literature review: Starting point


tDCS/tACS – E-field and J-field

- Parazzini et al., 2011
- tDCS 1mA
- Max induce E-Field 1.57 V/m
- Max J-current 0.043 A/m²
**tDCS/tACS – E-field**

- Merlet et al., 2011
- tDCS 1.12 mA
- Max induce E-Field 0.2 V/m
tDCS/tACS – J-field

- Laakso et al., 2013
- tACS 0.1 mA
- Max J-current 0.034 A/m²
Revisit of Relationship between Permissible Magnetic Field Strength and In-situ Electric Field Prescribed in the IEEE C95.6 Standard

K. Aga, A. Hirata, I. Laakso and K. Yamazaki
(Vick Chen, Xiyao Xin, Yinliang Diao)
Background

- Even though C95.1 (radio-frequency) standard consider anatomical human models for deriving the relationship between internal and external field strengths, ellipse is used in C95.6 (low frequency) standard.

- When deriving the relationship external magnetic field strength and internal field strength, the ellipsoid is used in the IEEE whereas anatomical body model is used in the ICNIRP.

- The relation between permissible magnetic field strength and in-situ electric field is revisited by some research groups.
MPE/RL of IEEE C95.6 and ICNIRP 2010

![Graph showing MPE/RL of Magnetic Field vs Frequency]

- IEEE (Controlled Environment)
- IEEE (General Public)
- ICNIRP (Occupational Exposure)
- ICNIRP (General Public Exposure)
Research Groups Joining Inter-comparison

- Nagoya Institute of Technology
  Computational method: SPFD method

- Aalto University
  Computational method: FEM with 1st order cubical elements

- Central Research Institute of Electric Power Industry
  Computational method: SPFD method

- Other two groups (Yinliang Diao, Vick Chen and his colleagues) have just provided data (today).
Human Models and Exposure Conditions

Human Models

<table>
<thead>
<tr>
<th>Name</th>
<th>Height [m]</th>
<th>Weight [kg]</th>
<th>Number of Tissues</th>
</tr>
</thead>
<tbody>
<tr>
<td>TARO</td>
<td>1.73</td>
<td>65</td>
<td>51</td>
</tr>
<tr>
<td>HANAKO</td>
<td>1.61</td>
<td>53</td>
<td>51</td>
</tr>
<tr>
<td>DUKE</td>
<td>1.74</td>
<td>70</td>
<td>77</td>
</tr>
<tr>
<td>ELLA</td>
<td>1.60</td>
<td>58</td>
<td>74</td>
</tr>
<tr>
<td>NORMAN</td>
<td>1.76</td>
<td>73</td>
<td>37</td>
</tr>
</tbody>
</table>

Exposure Conditions

- $B = 0.1$ mT
- $f = 50$ Hz, 1 MHz

$z$(TOP)  
$y$(AP)  
$x$(LAT)
Classification of Limbs

<IEEE C95.6 standard>
- Brain
- Heart
- Limbs
- Other tissues
## Computational Results

Comparison of basic restrictions and 99th percentile value of in-situ electric field [V/m].

<table>
<thead>
<tr>
<th>Tissues</th>
<th>IEEE C95.6</th>
<th>NIT</th>
<th>Aalto</th>
<th>CRIEPI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50 Hz</td>
<td>1 MHz</td>
<td>50 Hz</td>
<td>1 MHz</td>
</tr>
<tr>
<td>Brain</td>
<td>0.00163</td>
<td>0.00266</td>
<td>0.00255</td>
<td>0.00274</td>
</tr>
<tr>
<td>Heart</td>
<td>0.00425</td>
<td>0.00373</td>
<td>0.00240</td>
<td>0.00293</td>
</tr>
<tr>
<td>Limbs</td>
<td>0.00270</td>
<td>0.00403</td>
<td>0.00538</td>
<td>0.00412</td>
</tr>
<tr>
<td>Other tissues</td>
<td>0.00515</td>
<td>0.00579</td>
<td>0.00513</td>
<td>0.00600</td>
</tr>
<tr>
<td>Used DA model</td>
<td>N/A</td>
<td>Taro Hanako</td>
<td>Duke Ella</td>
<td>Norman Taro Hanako Duke Ella Norman</td>
</tr>
</tbody>
</table>

Gabriel’s parametric model at http://niremf.ifac.cnr.it/tissprop/

- Whole body exposure for all the parts (nonuniform exposure is not considered)
- "5 mm averaging" is not applied
- Heart apex is not discriminated
## Discussion

<table>
<thead>
<tr>
<th>Tissue</th>
<th>50 Hz</th>
<th>1 MHz</th>
<th>Multiplier to ICES (max)</th>
<th>DA model maximum</th>
<th>DA model average</th>
<th>std % to average</th>
<th>Multiplier to ICES (average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>0.00163</td>
<td>0.00306</td>
<td>1.88</td>
<td>0.00263</td>
<td>8.70</td>
<td>1.62</td>
<td></td>
</tr>
<tr>
<td>Heart</td>
<td>0.00425</td>
<td>0.00381</td>
<td>0.90</td>
<td>0.00301</td>
<td>24.0</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td>Limbs</td>
<td>0.00270</td>
<td>0.00739</td>
<td>2.73</td>
<td>0.00444</td>
<td>30.6</td>
<td>1.64</td>
<td></td>
</tr>
<tr>
<td>Other tissues</td>
<td>0.00515</td>
<td>0.00684</td>
<td>1.33</td>
<td>0.00587</td>
<td>9.80</td>
<td>1.14</td>
<td></td>
</tr>
</tbody>
</table>

### Brain Isolation

### Classification and Singular Point
Conclusion

• In-situ electric field in the brain exceeds the basic restriction.

• Good agreement was obtained in the in-situ electric field in the parts excluding limbs; definition of limbs.

• It is necessary to clearly mention about the classification of the limb.
IEEE ICES Standards Update

Dr. C-K. Chou*
TC95 Chairman
International Committee on Electromagnetic Safety (ICES)
Institute of Electrical and Electronics Engineers
Piscataway, NJ, USA

*Speaking as an individual and not for the IEEE
Outline

- IEEE ICES Organization
- TC34 standards
- TC95 standards
- C95.1 revision
  - Terminology changes
  - Limit changes
- Conclusions
ICES as the Focal Point in the Global Program for EM Safety Standards

Liaison with International Groups:
WHO, NATO, ITU, IEC, ICNIRP, ...

Liaison with National Groups:
ACGIH, NCRP, US Federal Agencies, Health Canada...

IEEE SASB

SCC-39 ICES AdCom

Management, Oversight, Representation...

TC-34: Product Standards
- SC-1
- SC-2

TC-95: Exposure Standards
- SC-1
- SC-2
- SC-3
- SC-4
- SC-5
- SC-6

TC-34
SC-1: Measurement Techniques
  - WG-1528: SAR compliance
  - WG-1528.5: 5G product compliance
SC-2: Computational Techniques
  - WG -1: General FDTD Requirements
  - WG-2: Vehicle mounted antenna configurations
  - WG-3: Mobile phones/personal wireless devices
  - WG-4: General FEM Requirements
  - WG 1528.6: 5G product compliance

TC-95
SC-1: Measurements and Calculations
SC-2: Warning Signs, Hazard Communications
SC-3: Low-frequency Exposure Limits
SC-4: High-frequency Exposure Limits
SC-5: Electro-explosive Devices
SC-6: EMF Modeling and Dosimetry
International Committee on Electromagnetic Safety

Scope

“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 humans, volatile materials, and explosive devices to such energy. Such standards will be based on established adverse health effects and will include safety levels for human exposure to electric, magnetic and electromagnetic fields, including induced currents from such fields, methods for the assessment of human exposure to such fields, standards for products that emit electromagnetic energy by design or as a by-product of their operation, and environmental limits.”
IEEE-SA Standards Process

- Open Process
- Consensus process
  - Allows for challenging and testing of all viewpoints
  - Balloting at Subcommittee and Sponsor levels
  - 75% of ballots must be returned with at least a 75% approval to reach consensus
- All negative comments and their resolutions must be recirculated

Examples:
- C95.6 (2002): 90% approval
- C95.1 (2005): 96% approval
- C95.1-2345 (2014): 98% approval
IEEE/ICES TC 34 update

Chairman: Dr. Jafar Keshvari
(Finland)
IEEE TC34 SC1 WG 1528
MEASUREMENT STANDARDS

- IEEE TC34 SC1 is responsible for the development of EMF measurement product standards.
- IEEE 1528 (head SAR measurement standard) was published in 2005, revised in 2013.
- Since 2010 TC 34 SC1 is jointly working with IEC TC106 at IEC MT1 & IEC PT62209-3 in developing SAR measurement for head and body SAR standards.
- In October 2017 a formal joint working group (JWG) was established at IEC TC106 and IEEE TC34 to publish an IEC/IEEE dual logo standard to replace IEEE 1528, IEC 62209-1 and IEC 62209-2 standards.
- The dual logo standard is planned to be published by 2019.
IEEE TC34 SC1 WG 1528.5
MEASUREMENT STANDARDS

- IEEE TC34 discussed the development of 5G mmWave Measurement compliance assessment product standard.
- IEEE Project Authorization Request (PAR) approved the IEEE 1528.5 project in December 2016.
- IEEE TC34 and IEC TC106 agreed to jointly develop the 5G mmWave measurement standard towards an IEC/IEEE dual logo standard.
- The first meeting of the joint working group will take place in Feb. 2018 in USA.
IEEE TC34 SC2

COMPUTATIONAL STANDARDS

- IEEE TC34 SC2 is responsible for the development of EMF computational standards.

- All computational standards are developed in joint working groups together with IEC TC106.

- Recently published COMPUTATIONAL standards are introduced in the next slides.

- These standards are excellent examples of how two large standardization organizations jointly have developed fully harmonized dual logo standards.
First SAR Computational Assessment
IEC/IEEE dual logo standards are Published

IEEE/IEC 62704-1 Ed.1. (WG Chair: Dr. Andreas Christ)
Part 1: General requirements for using the Finite Difference Time Domain (FDTD) method for SAR calculations

IEEE/IEC 62704-2 Ed.1. (WG Chair: Dr. Goga Bit-Babik)
Part 2: Specific requirements for finite difference time domain (FDTD) modelling of exposure from vehicle mounted antennas

IEEE/IEC 62704-3 Ed.1. (WG Chair: Dr. Vikass Monebhurrun)
Part 3: Specific Requirements for using the Finite Difference Time Domain (FDTD) Method for SAR Calculations of Mobile Phones
Activity update on IEEE/IEC 62704-4 (Finite Element Method)

IEEE/IEC 62704-4 Ed.1 (WG Chair: Dr. Andreas Christ)

Part 4: General requirements for using the Finite-Element Method (FEM) for SAR calculations and specific requirements for modelling vehicle-mounted antennas and personal wireless devices

- **Status**: The activity had been slow for some years because of the lack of contributions. From last year software manufacturers has become interested and now good progress is being made!

- **The plan is to have a committee draft for voting (CDV) by the end of 2018**
In Oct 2016 IEEE TC34 SC2 discussed the development of 5G computational mmWave compliance assessment product standard.

IEEE Project Authorization Request (PAR) approved the IEEE 1528.6 project in June 2017.

IEEE TC34 and IEC TC106 agreed to jointly develop the 5G mmWave computational standard towards IEC/IEEE dual logo standard.

The first meeting of the joint working group will be held in Feb. 2018 in USA.
IEEE Exposure Standards History

1960: USASI C95 Radiation Hazards Project and Committee chartered
1966: USAS C95.1-1966
   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 published on April 19, 2006 (comprehensive revision, 250 pages, 1143 ref.), Accepted by ANSI.
2014: IEEE C95.1-2345-2014 (0-300 GHz) (NATO/IEEE agreement)
2015: NATO adopted C95.1-2345-2014
## SCC39/TC95 Standards: Expiration Dates

<table>
<thead>
<tr>
<th>Number</th>
<th>Year</th>
<th>Approval Date</th>
<th>Expiration Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1460</td>
<td>1996</td>
<td>12/10/1996</td>
<td>12/31/2018</td>
</tr>
<tr>
<td>C95.1</td>
<td>2005</td>
<td>10/03/2005</td>
<td>12/31/2018</td>
</tr>
<tr>
<td>C95.1a</td>
<td>2010</td>
<td>02/02/2010</td>
<td>02/02/2020</td>
</tr>
<tr>
<td>C95.1-2345</td>
<td>2014</td>
<td>05/16/2014</td>
<td>12/31/2024</td>
</tr>
<tr>
<td>C95.2</td>
<td>1999</td>
<td>09/16/1999</td>
<td>12/31/2018</td>
</tr>
<tr>
<td>C95.3</td>
<td>2002</td>
<td>12/11/2002</td>
<td>12/31/2018</td>
</tr>
<tr>
<td>C95.3.1</td>
<td>2010</td>
<td>03/25/2010</td>
<td>03/25/2020</td>
</tr>
<tr>
<td>C95.4</td>
<td>2002</td>
<td>11/11/2002</td>
<td>12/31/2018</td>
</tr>
<tr>
<td>C95.6</td>
<td>2002</td>
<td>09/12/2002</td>
<td>12/31/2018</td>
</tr>
<tr>
<td>C95.7</td>
<td>2014</td>
<td>06/12/2014</td>
<td>12/31/2024</td>
</tr>
</tbody>
</table>
Free IEEE Safety Standards


- IEEE C95.1™-2005
  Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz

- IEEE C95.1a™-2010
  Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Field, 3 kHz to 300 GHz. Amendment 1: Specifies Ceiling Limits for Induced & Contact Current

- IEEE C95.1-2345™-2014
  Military Workplaces--Force Health Protection Regarding Personnel Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz

- IEEE C95.3™-2002
  Measurements and Computations of Radio Frequency Electromagnetic Fields with Respect to Human Exposure to Such Fields, 100 kHz-300 GHz

- IEEE C95.3.1™-2010
  Measurements and Computations of Electric, Magnetic, and Electromagnetic Fields with Respect to Human Exposure to Such Fields, 0 Hz to 100 kHz

- IEEE C95.6™-2002 (R2007)
  Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0-3 kHz

- IEEE C95.7™-2014
  Recommended Practice for Radio Frequency Safety Programs, 3 kHz to 300 GHz

Sponsored by the United States Navy, Air Force, and Army.
ICES TC95 Standards: Status

**C95.1-2005:** (Safety levels, 3 kHz – 300 GHz)
- Approved 2005; published 2006
- PAR for revision – approved June 2010, PAR extension request approved December 2014—**PAR expires 31 December 2018**
- Revision incorporates C95.6 (Safety levels, 0 Hz to 3 kHz)
- Stressing harmonization with ICNIRP guidelines
- Expect to initiate TC95 ballot January 2018; IEEE SA ballot mid-year 2018.

**PC95.1a:** (Safety levels, 3 kHz - 300 GHz)
- Published May 2010
- Amendment 1 (sets ceiling values for induced and contact current)
- Incorporated into C95.1-2005 revision
ICES TC95 Standards: Status

**C95.1-2345-2014:** (Safety levels, 0 Hz – 300 GHz)
- Approved 16 May 2014; published 30 May 2014
- Replaces NATO STANAG 2345

**C95.2-1999:** (RF energy and current flow symbols)
- Reaffirmed 2005
- PAR for Revision – approved November 2010; **Revised PAR approved February 2017**
- Completed TC95 ballot
- Now submitted for IEEE SA ballot
ICES TC95 Standards: Status

C95.3-2002: (RF measurements and computation: 100 kHz to 300 GHz)

- Reaffirmed 2008
- PAR for Revision – approved 6 February 2012; **PAR expires 31 December 2018**
- Revision incorporates C95.3.1 (measurements and computation: 0 Hz to 100 kHz)
- Expect to initiate TC95 ballot January 2018; IEEE SA ballot mid-year 2018.
ICES TC95 Standards: Status

**C95.4-2002**: (Safe distances from antennas during blasting operations)

- Reaffirmed 2008
- PAR for Revision – approved 22 September 2016; PAR expires 31 December 2018
- Revision submitted for TC95 ballot; IEEE-SA ballot by January 2018

**C95.6-2002**: (Safety levels – 0 to 3 kHz)

- Reaffirmed 2007
- Incorporated into C95.1-2005 revision (Safety levels, 0 kHz to 300 GHz)
ICES TC95 Standards: Status

**C95.7-2014**: (RF safety programs)
- Revision of C95.7-2005
- Approved 12 June 2014; published 8 August 2014

**1460-1996**: (Measurement of quasi-static electric and magnetic fields)
- Reaffirmed 2008
- Already incorporated into C95.3.1-2010
C95.1 Proposed Revision
Extensive Research Database

- The biological effects of RF exposure have been studied for about 70 years.

- Current IEEE database contains 6810 entries, of which 3671 are relevant to biological effects of RF exposure (January 23, 2018)

http://ieee-emf.com/
Topics numbered per the current C95.1 Annex B

B.5.1 Thermoregulation
B.5.2 Animal behavior, neurochemistry, neuropathology
B.5.3 Review of 0 Hz to 100 kHz studies
B.6.1 Teratogenicity, reproduction, and development
B.6.2 Hematology and endocrinology
B.6.3 Blood brain barrier (BBB) permeability
B.6.4 Eye pathology
B.6.5 Auditory pathology and RF hearing
B.6.6 Membrane biochemistry
B.6.7 Calcium studies and neuron conduction
B.6.8 Other types of animal studies
B.6.9 Human provocation studies
B.7.1 Animal cancer bioassays
B.7.2 Other animal and in vitro studies addressing cancer
B.7.3 Epidemiology studies (cancer and other endpoints)
B.8 Mechanisms
Dosimetry and exposure system quality evaluation
"Guidelines for the Systematic Review of Scientific Literature on Health and Electromagnetic Fields (0-300 GHz)“ (3/15/16)

- Review will focus on papers that have appeared after the cutoff date for coverage in the most recent WHO EHC reviews on ELF and RF fields (approximately 2006 and 2012-3, respectively).
- Review papers primary research papers that appear in journals that are indexed in PubMed or Web of Science.
- Topic review groups need to assess whether each study was appropriately designed, conducted and reported, using valid methodology, to support the conclusions in the paper.
Literature Review Status

- Focus on literature that is applicable to this frequency range (6-300 GHz) in order to make limited amendments to Annex B for this revision (which must be completed by December 31, 2017).

- Only a few of the review teams were able to perform a comprehensive literature review. Full reviews of all topics will be incorporated in the subsequent standard revision activity starting next January, and when finished will be included as an addendum of C95.1.
Exposure standard revision

- ICES is committed to the development of a science-based RF safety standard that is protective of public health, unambiguous, and practical to implement.
- The RF standard should be harmonized with other international standards to the extent where scientifically defensible.
# Editorial Working Group

<table>
<thead>
<tr>
<th>Name</th>
<th>Company/Institution</th>
<th>Role</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ralf Bodemann</td>
<td>Siemens AG</td>
<td>ICES Chairman</td>
<td>Germany</td>
</tr>
<tr>
<td>C-K. Chou</td>
<td>C-K. Chou Consulting</td>
<td>TC95 Chair</td>
<td>USA</td>
</tr>
<tr>
<td>Antonio Faraone</td>
<td>Motorola Solutions</td>
<td>Coordinator</td>
<td>USA</td>
</tr>
<tr>
<td>Ken Gettman</td>
<td>NEMA</td>
<td>ICES Vice Chair</td>
<td>USA</td>
</tr>
<tr>
<td>Kevin Graf</td>
<td>Exponent</td>
<td>SC3 Co-Chair</td>
<td>USA</td>
</tr>
<tr>
<td>Aki Hirata</td>
<td>Nagoya Institute of Technology</td>
<td>SC6 Chairman</td>
<td>Japan</td>
</tr>
<tr>
<td>Rob Kavet</td>
<td>EPRI (retired)</td>
<td>SC3 Co-Chair</td>
<td>USA</td>
</tr>
<tr>
<td>John Osepchuk</td>
<td>Full Spectrum Consulting</td>
<td>AdCom Emeritus</td>
<td>USA</td>
</tr>
<tr>
<td>Ric Tell</td>
<td>Richard A Tell and Associates</td>
<td>SC2 Chair</td>
<td>USA</td>
</tr>
<tr>
<td>Art Thansandone</td>
<td>Health Canada (retired)</td>
<td>SC4 Co-Chair</td>
<td>Thailand</td>
</tr>
<tr>
<td>Marv Ziskin</td>
<td>Temple University</td>
<td>SC4 Co-Chair</td>
<td>USA</td>
</tr>
<tr>
<td>Ron Petersen</td>
<td>R C Petersen Associates LLC</td>
<td>Executive Secretary</td>
<td>USA</td>
</tr>
<tr>
<td>Bill Bailey</td>
<td>Exponent</td>
<td>Invited expert</td>
<td>USA</td>
</tr>
<tr>
<td>Jerold Bushberg</td>
<td>University of California, Davis</td>
<td>Invited expert</td>
<td>USA</td>
</tr>
<tr>
<td>Robert Cleveland</td>
<td>FCC (retired)</td>
<td>Invited expert</td>
<td>USA</td>
</tr>
<tr>
<td>Ken Foster</td>
<td>University of Pennsylvania</td>
<td>Invited expert</td>
<td>USA</td>
</tr>
<tr>
<td>B Jon Klauenberg</td>
<td>US Air Force Research Laboratory</td>
<td>Invited expert</td>
<td>USA</td>
</tr>
<tr>
<td>Alexandre Legros</td>
<td>Lawson Health Research Institute and Western University</td>
<td>Invited expert</td>
<td>Canada</td>
</tr>
<tr>
<td>Pat Reilly</td>
<td>Metatec Associates</td>
<td>Invited expert</td>
<td>USA</td>
</tr>
<tr>
<td>Kenici Yamazaki</td>
<td>Central Research Institute of Electric Power Industry</td>
<td>Invited expert</td>
<td>Japan</td>
</tr>
</tbody>
</table>
Combining C95.6-2002 and C95.1-2005

- Different interaction mechanisms
  - Electrostimulation
  - Heating

- Different exposure quantities
  - In situ electric field, field intensity
  - SAR, power density

- Different safety factors
Terminology clarification

Clarify and convey more obvious meaning to some confusing or misleading terms and definitions.

- **RF radiation** ➞ **RF exposure**
  - Avoid confusion with ionizing radiation

- **Safety limits** ➞ **exposure limits**
  - Exposure limits with large safety margins

- **Action level** ➞ **unrestricted environments**
  - Avoids the term “uncontrolled” environment

- **Persons in controlled environments** ➞ **Persons permitted in restricted environments**
  - Under RF safety program C95.7-2014, there is a restricted environment
  - Persons permitted including the general public are allowed to enter, with exposure not to exceed the limit.
RF Safety Program (C95.7-2014)

- General public
- Unrestricted environment

RF Safety Program Required

- Restricted environment
- Experts Only

Persons are permitted to enter
Basic Restriction

Dosimetric Reference Limit (DRL)

- Recommended limits relative to dosimetric thresholds for *established adverse health effects* that incorporate appropriate *safety factors*.

- DRLs are expressed in terms of the *in situ* electric field strength (0 Hz to 5 MHz), SAR (100 kHz to 6 GHz), or *penetrating power density* at surface (6 GHz to 300 GHz).
MPE ➔ Exposure Reference Level (ERL)

- The highest level of an electric field, magnetic field, electromagnetic field, induced current or contact current to which the standard permits exposure, and which includes an adequate margin of safety against established adverse health effects.

- The ERL is expressed as a metric appropriate to the frequency and temporal characteristics of the exposure. The ERL is based on the dosimetric reference limit (DRL – in situ electric field, SAR, or penetrating power density) and may be exceeded if it can be demonstrated that the corresponding DRL is not exceeded.

- ERLs are sometimes called reference levels, derived limits, permissible exposure limits, maximum permissible exposure values, or investigation levels.
Below 100 kHz

- Both DRL and ERL are kept the same until next revision.
- TF1 on CNS (Alexandre Legros)
  - Little justification for considering phosphenes themselves as adverse.
  - Conversion of those DRLs to new ERLs using a detailed anatomical induction model.
  - Before new limits are derived, retention of existing CNS DRLs
  - Provide interim edits that can be implemented by Dec. 31, 2017, with the intention to do a more thorough study during 2018. This could be followed by a more comprehensive revision to the CNS limits during 2019.
- TF2 on PNS (Kenichi Yamazakai)
  - A few questions remain to be resolved with TF-2. Some modifications can be accomplished within the December 31, 2017 deadline.
Keep the same limits for SAR and incident power density, except harmonize with ICNIRP on ERL in restricted environments for frequencies above 300 MHz, and move SAR top frequency from 3 GHz to 6 GHz.

Change averaging time to be mass based, whole body exposure 30 minutes, local exposure 6 minutes.

Change extremities to limbs to harmonize.
Revising limits above 6 GHz

- A consistent level of protection against thermal hazards below and above the transition frequency of 6 GHz
- Modeling studies based on a standard theoretical model for heating of tissue (bioheat equation) [Foster et al. 2016, 2017; Morimoto et al. 2016, Hashimoto et al., 2017; Sasaki et al. 2017].
- The ERL for whole body and DRL for local exposure in the frequency range 6-300 GHz were chosen based on two considerations:
  - (a) to maintain a similar total absorbed power in the body from whole body exposures at the ERL below and above the transition frequency;
  - (b) to maintain a similar peak temperature increase in tissue produced by RF exposure across the transition.
- The fivefold difference in exposure between unrestricted and restricted exposure conditions (safety factor of 5) is maintained across the entire frequency range up to 300 GHz.
Revising limits above 6 GHz (2)

- A number of computational modeling studies reviewed in Foster et al. (submitted) show that in the frequency range 0.1-6 GHz the heating factor is approximately 0.25 °C/(Watt/kg), corresponding to a peak temperature increase of approximately 2.5 °C at the DRL below 6 GHz for restricted exposure conditions.

- To provide consistency, the same theory (based on Pennes’ bioheat equation) was used to determine the ERL and DRL maximum increase in skin temperature at approximately the 2-3 °C over the entire frequency range (restricted exposure conditions). The analysis for exposures from 6-300 GHz relies on a modeling study by Sasaki et al. (2017).

- Based on current data and analysis, as well as previous analysis of far infrared safety limits, the present limits are conservative against thermal hazards.
Table A1. Model results, assuming $I_o = 100$ W m$^{-2}$. Foster et al. [2017]

<table>
<thead>
<tr>
<th>Frequency, GHz</th>
<th>Energy transmission coefficient into skin $T_r^a$</th>
<th>Energy penetration depth L (mm)$^a$</th>
<th>Steady state temperature increase, °C$^b$</th>
<th>Steady state temperature increase, °C [analytical approximation, from eqn. (A6) using $T_r$ from this table]</th>
<th>Time to reach 90% of steady state temperature increase, s$^b$</th>
<th>Temperature increase after 10 s of exposure, °C$^b$</th>
<th>Time at which the response to a 10 s pulse has fallen to 1/e of its peak value, s$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.47</td>
<td>9.4</td>
<td>0.39</td>
<td>0.89</td>
<td>925</td>
<td>0.012</td>
<td>&gt;100</td>
</tr>
<tr>
<td>10</td>
<td>0.49</td>
<td>1.9</td>
<td>0.74</td>
<td>0.93</td>
<td>775</td>
<td>0.05</td>
<td>86</td>
</tr>
<tr>
<td>30</td>
<td>0.54</td>
<td>0.43</td>
<td>0.98</td>
<td>1.0</td>
<td>800</td>
<td>0.13</td>
<td>26</td>
</tr>
<tr>
<td>100</td>
<td>0.70</td>
<td>0.18</td>
<td>1.31</td>
<td>1.33</td>
<td>650</td>
<td>0.18</td>
<td>18</td>
</tr>
<tr>
<td>300</td>
<td>0.84</td>
<td>0.14</td>
<td>1.58</td>
<td>1.60</td>
<td>650</td>
<td>0.22</td>
<td>18</td>
</tr>
</tbody>
</table>

$^a$Calculated from thermal properties of dry skin from Hasgall et al. (2015) and dielectric properties for dry skin from Gabriel et al. (1996).$^b$ Calculated numerically from BHTE assuming an adiabatic half plane of tissue assuming thermal properties of dry skin (Hasgall et al. 2015).
<table>
<thead>
<tr>
<th>Frequency GHz</th>
<th>ERL local (restricted)</th>
<th>DRL local (restricted environment)</th>
<th>ERL (whole body) (restricted environment)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incident power density to produce 2-3 °C temperature rise</td>
<td>Penetrating (absorbed) power density at that incident power density W/m²</td>
<td>Incident power density on 1 m² surface so total absorbed power is 40 W*</td>
</tr>
<tr>
<td>6</td>
<td>260</td>
<td>200</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ramp down as power function of f)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>235</td>
<td></td>
<td>103</td>
</tr>
<tr>
<td></td>
<td>(ramp down as power function of f)</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>160</td>
<td>(ramp down as power function of f)</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>(ramp down as power function of f)</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>100</td>
<td>129</td>
<td>(ramp down as power function of f)</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>(ramp down as power function of f)</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>300</td>
<td>108</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>48</td>
</tr>
</tbody>
</table>


*Assuming 100 kg person, exposed surface area of skin 1 m².
\[ I_0 = 100 \text{ W/m}^2 \]

- Multilayer forearm (Sasaki)
- Multilayer abdomen (Sasaki)
- Homogeneous – surface heating
- Homogeneous – finite penetration depth

- Forearm
- Abdomen
- Foster finite element
- Foster - surface approximation
Sasaki et al. [2017]

doubling of transmission coefficient at the high frequency end
Short millimeter wave pulses (30-300 GHz).

- These limits are based on a thermal analysis that shows that exposure to brief (10 sec) high intensity pulses at millimeter wave frequencies can produce thermal hazards (Foster et al. 2017).
- Currently such exposures might be produced by some military nonlethal weapons (which are not in the purview of the present standard) but future sources of high powered mm wave or terahertz energy for industrial applications might pose similar hazards.
- Fluence is the power density of the RF energy integrated over pulse time, i.e., the energy density of a pulse, must be lower than \((\text{pulse width in seconds})^{1/2} \text{kJ/m}^2\) for 1 °C temperature rise.
- It is anticipated that most such sources will be sufficiently distant from the body that free space power density can be used to assess compliance with these limits.
Temperature rise from a short pulse

\[ T_{\text{sur}}(t) = \frac{I_0 T_{tr} R_1}{k} \text{erf}\left(\sqrt{\frac{t}{\tau_1}}\right) \degree C \]

\[ = 0.019 I_0 T_{tr} \text{erf}\left(\sqrt{\frac{t}{\tau_1}}\right) \degree C \]

\[ T_{\text{sur}}(\tau) \approx 10^{-3} I_0 T_{tr} \sqrt{\tau} \degree C. \]  

To limit the increase in skin temperature to 1\degree C, this implies that the fluence (integral of the absorbed power density over the pulse duration) should be limited to about \(10^3 \tau^{1/2}\) J m\(^{-2}\). The pulses must be far enough apart in time for the tran-

Walters et al. (2000)

Foster et al. (2017)
Revised Table 5
DRLs for frequencies between 100 kHz and 6 GHz

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Persons in unrestricted environments</th>
<th>Persons permitted in restricted environments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SAR (W/kg)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>SAR (W/kg)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Whole-body exposure</td>
<td>0.08</td>
<td>0.4</td>
</tr>
<tr>
<td>Local exposure&lt;sup&gt;b&lt;/sup&gt; (head and torso)</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Local exposure&lt;sup&gt;b&lt;/sup&gt; (Limbs and pinnae)</td>
<td>4</td>
<td>20</td>
</tr>
</tbody>
</table>

<sup>a</sup> SAR is averaged over 30 minutes for whole body exposure and 6 minutes for local exposure.

<sup>b</sup> Averaged over any 10 g of tissue (defined as a tissue volume in the shape of a cube).
### Table 6 Local exposure DRL for frequencies between 6 and 300 GHz

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Penetrating power density at skin surface (W/m²)(^a,(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Persons in unrestricted environments</td>
</tr>
<tr>
<td>6 GHz to 300 GHz</td>
<td>20</td>
</tr>
</tbody>
</table>

\(^a\) Penetrating power density at skin is averaged over 6 min for local exposure.

\(^b\) Averaged over any 4 cm\(^2\) of skin surface for 6 GHz to 30 GHz, and 1 cm\(^2\) for 30 GHz to 300 GHz (area defined as surface of skin in the shape of a square).
### Table 7

**RMS values of the whole body exposure ERLs for persons in unrestricted environments**

<table>
<thead>
<tr>
<th>Frequency range (MHz)</th>
<th>Electric field strength (E)&lt;sup&gt;a&lt;/sup&gt; (V/m)</th>
<th>Magnetic field strength (H)&lt;sup&gt;a&lt;/sup&gt; (A/m)</th>
<th>Power density (S) E-field, H-field (W/m&lt;sup&gt;2&lt;/sup&gt;)</th>
<th>Averaging time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1–1.34</td>
<td>614</td>
<td>16.3 / f&lt;sub&gt;M&lt;/sub&gt;</td>
<td>(1000), (100 000 / f&lt;sub&gt;M&lt;/sub&gt;&lt;sup&gt;2&lt;/sup&gt;)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>30</td>
</tr>
<tr>
<td>1.34–3</td>
<td>823.8 / f&lt;sub&gt;M&lt;/sub&gt;</td>
<td>16.3 / f&lt;sub&gt;M&lt;/sub&gt;</td>
<td>(1800 / f&lt;sub&gt;M&lt;/sub&gt;&lt;sup&gt;2&lt;/sup&gt;), (100 000 / f&lt;sub&gt;M&lt;/sub&gt;&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>30</td>
</tr>
<tr>
<td>3–30</td>
<td>823.8 / f&lt;sub&gt;M&lt;/sub&gt;</td>
<td>16.3 / f&lt;sub&gt;M&lt;/sub&gt;</td>
<td>(1800 / f&lt;sub&gt;M&lt;/sub&gt;&lt;sup&gt;2&lt;/sup&gt;), (100 000 / f&lt;sub&gt;M&lt;/sub&gt;&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>30</td>
</tr>
<tr>
<td>30–100</td>
<td>27.5</td>
<td>158.3 / f&lt;sub&gt;M&lt;/sub&gt;&lt;sup&gt;1.668&lt;/sup&gt;</td>
<td>(2), (9 400 000 / f&lt;sub&gt;M&lt;/sub&gt;&lt;sup&gt;3.336&lt;/sup&gt;)</td>
<td>30</td>
</tr>
<tr>
<td>100–400</td>
<td>27.5</td>
<td>0.0729</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>400–2,000</td>
<td>—</td>
<td>—</td>
<td>f&lt;sub&gt;M&lt;/sub&gt;/200</td>
<td>30</td>
</tr>
<tr>
<td>2,000–300,000</td>
<td></td>
<td></td>
<td>10</td>
<td>30</td>
</tr>
</tbody>
</table>

**NOTE**—f<sub>M</sub> is the frequency in MHz.

1. Averaging time changed to 30 minutes, because of the whole body exposure.
Table 8

RMS values of the whole body exposure ERLs for persons permitted in restricted environments

<table>
<thead>
<tr>
<th>Frequency range (MHz)</th>
<th>Electric field strength $(E)^a$ (V/m)</th>
<th>Magnetic field strength $(H)^a$ (A/m)</th>
<th>Power density $(S)$ E-field, H-field (W/m²)</th>
<th>Averaging time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1–1.0</td>
<td>1842</td>
<td>16.3 / $f_M$</td>
<td>(9000), (100 000 / $f_M^2$)</td>
<td>30</td>
</tr>
<tr>
<td>1.0–30</td>
<td>$1842 / f_M$</td>
<td>16.3 / $f_M$</td>
<td>(9000 / $f_M^2$), (100 000 / $f_M^2$)</td>
<td>30</td>
</tr>
<tr>
<td>30–100</td>
<td>61.4</td>
<td>16.3 / $f_M$</td>
<td>(10), (100 000 / $f_M^2$)</td>
<td>30</td>
</tr>
<tr>
<td>100–400</td>
<td>61.4</td>
<td>0.163</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>400–2,000</td>
<td>—</td>
<td>—</td>
<td>$f_M/40$</td>
<td>30</td>
</tr>
<tr>
<td>2000–300,000</td>
<td>—</td>
<td>—</td>
<td>50</td>
<td>30</td>
</tr>
</tbody>
</table>

NOTE—$f_M$ is the frequency in MHz.

1. Averaging time changed to 30 minutes, because of the whole body exposure.
2. Change ramp frequency from 300 to 400 MHz. and keep the same ratio of 5 between restricted and unrestricted environment. Also harmonized with ICNIRP.
### Table 9
**RMS values of the local exposure ERLs between 6 and 300 GHz**

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Persons in unrestricted environments</th>
<th>Persons permitted in restricted environments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incident Power Density (W/m²)(^{a b c})</td>
<td>Incident Power Density (W/m²)(^{a b c})</td>
</tr>
<tr>
<td>6 GHz</td>
<td>40</td>
<td>200</td>
</tr>
<tr>
<td>6 GHz – 300 GHz</td>
<td>(55f_G^{-0.177})</td>
<td>(275f_G^{-0.177})</td>
</tr>
<tr>
<td>300 GHz</td>
<td>20</td>
<td>100</td>
</tr>
</tbody>
</table>

\(^{a}\) Incident power density is averaged over 6 min for local exposure.

\(^{b}\) Averaged over any 4 cm² of skin surface for 6 to 30 GHz, and 1 cm² for 30 GHz to 300 GHz (area defined as surface of skin in the shape of a square).

\(^{c}\) Measured in air at normal usage distance from body.
## Induced and contact current limits

**Table 11 — RMS induced and contact current limits for continuous sinusoidal waveforms: (100 kHz to 110 MHz)**

<table>
<thead>
<tr>
<th></th>
<th>Persons in Unrestricted Environments</th>
<th>Persons in Permitted in Restricted Environments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency</strong></td>
<td>100 kHz – 3 MHz</td>
<td>3 MHz – 30 MHz</td>
</tr>
<tr>
<td></td>
<td>30 MHz – 110 MHz</td>
<td>100 kHz – 3 MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 MHz – 30 MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30 MHz – 110 MHz</td>
</tr>
<tr>
<td><strong>Induced, each foot</strong></td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td><strong>Contact, grasp a</strong></td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>100(f/3)^{0.3}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
</tr>
<tr>
<td><strong>Contact, touch</strong></td>
<td>16.7</td>
<td>16.7(f/3)^{0.3}</td>
</tr>
<tr>
<td></td>
<td>33.4</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50(f/3)^{0.3}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

**NOTE 1**—Tabulated values are rms values; \( f \) = frequency in MHz.
Intense Pulses Fluence limits

For very intense pulses in the millimeter wave frequency range (30-300 GHz) of less than 10 seconds in duration and greater than 30 seconds apart for the temperature rise to decay, the maximum fluence (incident power density integrated over the pulse duration) shall be limited to:

Restricted environments:
1 (pulse width in seconds)$^{1/2}$ kJ/m$^2$

Unrestricted environments:
0.2 (pulse width in seconds)$^{1/2}$ kJ/m$^2$
Local exposure ERL below 6 GHz

C95.1-2005, section 4.6 Relaxation of the power density MPEs for localized exposures

- The spatial maximum value of the power density or mean squared field strength shall not exceed 20 times the square of the allowed spatially averaged values Table 7 at frequencies below 400 MHz, and shall not exceed the equivalent power density of 40 W/m² at frequencies between 400 MHz and 6 GHz.

- The spatial peak value of the power density or mean squared field strength should not exceed 20 times the square of the allowed spatially averaged values of the fields and 20 times the allowed power density (Table 8) at frequencies below 400 MHz, and should not exceed the equivalent power density of 200 W/m² at frequencies between 400 MHz and 6 GHz.

- However, Findlay and Dimbylow (2009) [B52] have shown that the specified local exposure ERLs for both upper and lower tiers do not necessarily protect against exceeding the underlying DRL in all cases of exposure.

- Users of the ERLs for local exposure should be aware of these limitations. Revision will be in the future.
Conclusions

- Updated status of both IEEE proposed human exposure assessment and exposure standards.
- C95.6-2002, C95.1-2005 and C95.1-2345-2014 standards are developed to protect against established adverse health effects.
- Combination of C95.6 and C95.1 is in progress.
- Terminology changes to clarify and convey more obvious meaning to these terms.
- Exposure limits above 6 GHz are revised based on recent thermal modeling studies.
- ICES considers harmonization with ICNIRP and the European Union Directives important, with an ultimate goal of internationally-harmonized EMF exposure criteria.
One sun in the sky

Thank you

Contact: ck.chou@ieee.org
MWF Comments on the proposed limits above 6 GHz:

1. The MWF appreciates that the half wavelength requirement has been removed from both local DRL and ERL tables.

2. The MWF accepts that the thermal data from Sasaki et al. [2017] and Foster et al. [2017] are quite consistent but we are still of the view that these data do not preclude penetrating power PD limits (for persons in unrestricted environment) in the order of 100 W/m² averaged over 1 cm² and/or 50 W/m² averaged over 4 cm² at 6 GHz – 300 GHz. The MWF suggests that the discussion on the limit values should take into consideration of the work of Dr Leeor Alon which should be concluded in the next few months. If as we expect, the research of Dr Alon will show the temperature increase is well below 2-3°C temperature rise in the skin at these incident power densities a discussion of the basis for the safety factor of 10 may be warranted.

3. The MWF disputes that alignment with the laser standard at 300GHz is sufficient to justify the change in averaging area at 30GHz from 4cm² to 1cm². There already exists a very significant discontinuity at 300GHz in terms of the power density limits. We suggest that the TC95 consider the change in averaging area at 100GHz rather than 30GHz.

4. The MWF again recommends that the standard only refer to incident PD limits. If the Committee decides to continue with the penetrating power density (PPD) DRL, the MWF recommends that a general statement be included to the effect that compliance with the incident power density limits are sufficient to show compliance of products, as it is not possible to be aware of all possible coupling conditions and the absorption at mmW frequencies will occur almost entirely within the skin and the measurement of PPD will be as difficult and as challenging as trying to measure SAR very close to the surface of the phantom.
Further Comments on the IEEE C95.1 Revision

January 23rd 2018
Chandler, AZ, USA
Penetrating power PD limits (for persons in unrestricted environment) in the order of 100 W/m² averaged over 1 cm² and/or 50 W/m² averaged over 4 cm² seems justifiable at 6 GHz – 300 GHz.

The change in the averaging area at 30 GHz from 4 cm² to 1 cm² does not seem justified and will introduce unnecessary discontinuities.

Consider introducing revised PPD limits for extremities (like it is currently done for SAR).

Thermal data from Sasaki et al. [2017] and Foster et al. [2017] are quite consistent but the MWF is still of the view that these data do not preclude penetrating power PD limits (for persons in unrestricted environment) in the order of 100 W/m² averaged over 1 cm² and/or 50 W/m² averaged over 4 cm² at 6 GHz – 300 GHz.

IEEE C95.1 draft limits are unlikely to resolve the discontinuity in Pmax at the transition from SAR to PD.

The MWF argues that alignment with the laser standard at 300 GHz is not sufficient to justify the change in averaging area at 30 GHz from 4 cm² to 1 cm². There already exists a very significant discontinuity at 6 GHz in terms of the power density limits. We suggest that the TC95 consider the change in averaging area at 100 GHz rather than 30 GHz.

Extremities are subjected to broad skin temperature excursions in everyday life without apparent harmful effects.
Further comments

- The limiting (thermal) hazard at the mmW is expected to be skin heating not increases in core body temperature. At or around 30 GHz, the same limits intended to be averaged over a small area should be applicable to prevent from whole-body heat stress.

  From Ziskin et al, “Tissue Models for RF Exposure Evaluation at Frequencies above 6 GHz”, submitted to *Bioelectromagnetics*: “We estimate that prolonged whole body exposure to RF energy above 6 GHz that would be sufficient to raise core body temperature by 1 C would result in increases in skin temperature of approximately 40 C. Consequently, the limiting (thermal) hazard in this frequency range is skin heating, not increases in core body temperature.”

- It is suggested to include a general statement to the effect that compliance with the incident power density limits are sufficient to show compliance of products.

  Measurement of PPD will be as difficult and as challenging as trying to measure SAR very close to the surface of the phantom and not likely possible for the foreseeable future.
Potential implications on $P_{\text{max}}$

<table>
<thead>
<tr>
<th>Freq (GHz)</th>
<th>Array size $2 \times 2$ – $10 \times 10$ elements (cm$^2$)</th>
<th>ERL (IPD limit) (W/m$^2$) avg: 1 cm$^2$</th>
<th>Max power (dBm)</th>
<th>Max power (dBm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tablets, handsets, wearables ($\text{IUD} = 0.5$ cm)</td>
<td>30</td>
<td>1 – 25</td>
<td>30</td>
<td>$\approx 5.5 – 14.5$</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>0.6 – 14.1</td>
<td>29</td>
<td>$\approx 5.5 – 12.5$</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>0.4 – 9</td>
<td>28</td>
<td>$\approx 5.5 – 10.5$</td>
</tr>
</tbody>
</table>

$P_{\text{max}}$ is determined according to ERL: $55^*f^{0.177}$ W/m$^2$.

Preliminary assessment based on square arrays.

For different antenna designs and exposure conditions $P_{\text{max}}$ might differ.

$P_{\text{max}}$ is well-below the UE power levels used in current mobile communication systems (i.e. for $f < 6$ GHz). This will lead to difficulties in meeting 3GPP specifications for 5G New Radio.
Thank you

Michael Milligan
Secretary General
Mobile & Wireless Forum
www.mwfai.org
michael.milligan@mwfai.org
SC3/4 Meeting
Chandler, Arizona
January 23, 2018
Purpose of IEEE Database

The primary purpose of the IEEE (Institute of Electrical and Electronics Engineers) database (ieee-emf.com) is to provide a comprehensive database of the world’s English language literature on radiofrequency (RF) energy to support the review and revision, if needed, of RF exposure standards published by IEEE. The goal is to identify all peer-reviewed research papers and other relevant reports such as peer-reviewed review articles and letters to journal editors. Many of the research papers have a link to abstracts in PubMed.

The database can be searched by a number of ways (author, study type, key word, year, frequency range, etc.). The core of the database is available without charge to the public; however, members of IEEE ICES (International Committee on Electromagnetic Safety) who are writing reviews of specific research areas have access to a password-protected area to support their work.
As of January 19, 2018, Database had

- 6809 citations
- 6194 papers (PDF files).
- About 91% of citations have PDF file

Since June 1, 2016:

+ 505 new citations
+ 570 PDF files
Recent Contributors of PDF Files for IEEE Database

Marvin Ziskin
Mario Cvetkovic
CK Chou
Antonio Faraone
Goga Bit-Babik
Vijayalaxmi
Ken Foster