1. **Call to Order**
   The meeting was called to order by Chairman C-K. Chou at 09:00 h.

2. **Introduction of those Present**
   Each of the 15 attendees introduced her/himself.

3. **Approval of Agenda**
   Following a motion by J. Bushberg that was seconded by R. Bodemann, the agenda was approved.

4. **Approval of the Minutes from Fort Sam Houston, San Antonio, 18 January 2013 Meeting**
   Following a motion by M. Ziskin and seconded by J. Bushberg, the minutes were approved.

5. **Report of ICES Chairman - R. Bodemann**
   a) The web site designer will resign within the next few months. Future support of web site by IEEE is not known, but will be followed up.
   b) The ICES ADCOM will hold a teleconference in July.
   c) European Directive – Regulation of Electromagnetic Fields for Occupational Health. Sets limits and action levels that will become binding in three years. It is heavily based on ICNIRP 1998. Not designed for military applications. Note the limits can be exceeded if it can be proven that there will be no adverse health effect. Individual countries can adopt lower limits (more conservative), but can not permit higher exposure values. See Attachment 1 for details concerning the proposed limits.

6. **Report of TC95 Chairman – C-K Chou**
   a) Ellie Adair memorial. Comments were made on the many important contributions of Ellie Adair to the basic science of thermal regulation and response to EMFs in both monkeys and humans. Her research results have been instrumental in setting standards for preventing adverse health effects in humans.
b) PIERS 2013 meeting took place in Taipei. Many good papers of interest were presented including: *Do Microwaves Induce Free Radicals in Food or Tissues?* by J. Osepchuk, R. Schiffmann, and C-K Chou; and *An Update of IEEE C95.1 Exposure Standard Revision* by members of SC3/4. More details can be found in Attachment 2 – TC95 Chairman Report.


The Secretary’s report was presented by C-K Chou in the absence of R. Petersen. See Attachment 3 – Secretary’s Report for complete details.

8. Treasurer’s Report – R. Petersen

The Treasurer’s report was presented by C-K Chou in the absence of R. Petersen. See Attachment 4 – Treasurer’s Report for complete details.

9. Membership Report – M. Murphy

In the absence of M. Murphy there was no Membership report presented at the meeting. However, there was prepared a complete current list of IEEE TC95 members who are listed on the ICES website. See Attachment 5.

10. Technical Presentation

An excellent presentation entitled RF Safety Testing Using Magnetic Resonance Imaging was given by Leeor Alon. See Attachment 6.

11. FCC RF Safety Report and Order

R. Cleveland gave a summary of Bob Weller’s slide presentation entitled, RF Safety Report and Order: ET Docket No. 03-137, May 24, 2013. See Attachment 7 for full details.

12. Reports from the Subcommittees

a) SC1 (Measurements and Computations) Report was given by M. Douglas

b) SC2 (Safety Programs) Report was given by R. Cleveland

c) SC3/4 (Safety Levels – 0 Hz to 300 GHz) Report was given by M. Ziskin.

13. Old Business

C-K Chou reminded everyone that if they hadn’t already done so, should submit their name, phone, and email address plus a short biographical sketch of no more than 300 words to be posted on the ICES web site.

14. New Business

No new business.

15. Next Meeting

The next meeting of ICES will be held at the Motorola Company Building in Plantation, Florida on January 14-16, 2014.

16. Adjournment

The meeting was adjourned at 16:30 h by Chairman C-K Chou following a motion by M. Ziskin.

*These minutes are respectfully submitted by M. Ziskin, in the absence of Secretary R. Petersen.*
**Sign-in Sheet**  
**TC95 Meeting, 8 June, 2013**  
**Thessaloniki, Greece**

<table>
<thead>
<tr>
<th>Last Name</th>
<th>First Name</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Alon</td>
<td>Leeor</td>
<td>NY University</td>
</tr>
<tr>
<td>2. Bodemann</td>
<td>Ralf</td>
<td>Siemens</td>
</tr>
<tr>
<td>3. Bushberg</td>
<td>Jerry</td>
<td>UC Davis</td>
</tr>
<tr>
<td>4. Choi</td>
<td>Dong-geun</td>
<td>Ministry of Science, ICT</td>
</tr>
<tr>
<td>5. Chou</td>
<td>Chung-Kwang</td>
<td>Motorola Solutions</td>
</tr>
<tr>
<td>6. Cleveland</td>
<td>Robert</td>
<td>EMF Consulting</td>
</tr>
<tr>
<td>7. Douglas</td>
<td>Mark</td>
<td>IT’IS Foundation</td>
</tr>
<tr>
<td>8. Elder</td>
<td>Joe</td>
<td>Independent Consultant</td>
</tr>
<tr>
<td>9. Gallant</td>
<td>Josette</td>
<td>Industry Canada</td>
</tr>
<tr>
<td>10. Harmon</td>
<td>Ray</td>
<td>URS</td>
</tr>
<tr>
<td>11. Karpowicz</td>
<td>Jolanta</td>
<td>CIOP PIB</td>
</tr>
<tr>
<td>12. Kim</td>
<td>Ki Hwea</td>
<td>Ministry of Science, ICT</td>
</tr>
<tr>
<td>13. Kim</td>
<td>Nam</td>
<td>Chungbuk University</td>
</tr>
<tr>
<td>14. Lee</td>
<td>Ae-Kyoung</td>
<td>ETRI</td>
</tr>
<tr>
<td>15. Ramachandran</td>
<td>T V</td>
<td>Vodaphone</td>
</tr>
<tr>
<td>17. Toropainen</td>
<td>Anssi</td>
<td>Nokia</td>
</tr>
<tr>
<td>18. Ziskin</td>
<td>Marvin</td>
<td>Temple University</td>
</tr>
</tbody>
</table>
**Approved Agenda**  
**ICES TC95 Meeting**  
Makedonia Palace Hotel  
Thessaloniki, Greece  
Friday, 8 June 2013  
0830 – 1200

1. **Call to Order**  
2. **Introduction of those Present**  
3. **Approval of Agenda**  
4. **Approval of 18 January 2013 TC95 minutes**  
5. **ICES Chairman’s Reports**  
6. **TC95 Chairman’s Report**  
7. **Executive Secretary’s Report**  
8. **Treasurer’s Report**  
9. **Membership Chairman’s Report**  
10. **Topic presentations**  
    a) A novel method for quantification of RF safety using MRI  
    b) To be determined  
11. **Reports from the Subcommittees**  
    a) SC1 (Measurements and computations)  
    b) SC2 (Safety programs)  
    c) SC3 (Safety levels – 0 Hz to 3 kHz)  
    d) SC4 (Safety levels – 3 kHz to 300 GHz)  
    e) SC5 (Effects of EM fields on blasting operations)  
12. **ICES Website Improvement**  
13. **New Business**  
14. **Future Meetings**  
    a) January 2014, California or Florida  
15. **Adjourn**
Exposure Limit Values (ELVs)

in situ electric field strength (peak) in V/m vs Frequency in Hz

- Health Effect ELVs
- Sensory Effect ELVs
Action Levels (ALs) for external electric fields

- **Low ALs**
- **High ALs**

Electric field strength in V/m vs. Frequency in Hz
Action Levels (ALs) for external magnetic fields

- **Low ALs**
- **High ALs**
- **Limb ALs**

**Magnetic Field Density in µT**

**Frequency in Hz**
TC 95 Chairman Report

C-K. Chou

June 8, 2013

Thessaloniki, Greece
PIERS 2013 Taipei meeting (1)

- Organized a session “Biological Effects and Medical Applications of Electromagnetic Energy” held on March 26, 2013
- 17 papers presented
- Safety relevant papers
  - Do Microwaves Induce Free Radicals in Food or Tissues? John Osepchuk (Full Spectrum Consulting, USA), Bob Schiffmann (R. F. Schiffmann Associates, Inc., USA), and Chung-Kwang Chou (Motorola Solutions, Inc., USA)
  - Thermal Dosimetry and Thermodynamics of In Vitro RF Bioassays. Quirino Balzano (University of Maryland, USA), Asher R. Sheppard (Asher Sheppard Consulting, USA), and Giorgi Bit-Babik (Motorola Labs, USA)
  - Calculation of SAR and Temperature Increase in Human Bodies Due to on-body Communications at 900 MHz Hsing-Yi Chen (Yuan Ze University, Taiwan) and Heng-Ming Lee (Yuan Ze University, Taiwan)
  - Normalization of the Peak Spatial Absorption Rate for the Simulation of Wireless Communication Devices Jafar Keshvari (Nokia Corporation, Finland) and Andreas Christ
PIERS 2013 in Taipei (2)

– Evaluation on Electromagnetic Interference of Implanted Cardiac Pacemaker by Mobile Phone Yuta Endo (Chiba University, Japan), Kazuyuki Saito (Chiba University, Japan), Soichi Watanabe (National Institute of Information and Communications Technology, Japan), Masaharu Takahashi (Chiba University, Japan), and Koichi Ito (Chiba University, Japan)

– Active Implantable Medical Devices and Electromagnetic Compatibility, Veronica Ivans (Medtronic CRDM, USA) and Chung-Kwang Chou (Motorola Solutions, Inc., USA)

– Interesting Issues of Mobile Phones and Base Stations in Taiwan, Ji-Shing Lin (Taiwan Telecommunication Industry Development Association, Taiwan)

– Impact of Planning Based Restrictions on Operation of Mobile Networks, Jack Rowley (GSM Association, UK)

– Occupational Over-exposure to RF Radiation in TV Tower, Maila Hietanen (Finnish Institute of Occupational Health, Finland)

– Update of IEEE C95.1 Exposure Standard Revision, Chung-Kwang Chou (Motorola Solutions, Inc., USA), J. Patrick Reilly (Metatec Associates, USA), R. Kavet (Electric Power Research Institute, USA), Bertram J. Klauenberg (Air Force, USA), Marvin C. Ziskin (Temple University Medical School, USA), Art Thansandote (Health Canada, Canada), Thanh Dovan (SP AusNet, Australia), R. A. Tell (International Committee on Electromagnetic Safety, Subcommittee 4, USA), Ken Gettman (National Electrical Manufacturers Association, USA), Ralf Bodemann (Siemens Inc., Germany), and R. C. Petersen (International Committee on Electromagnetic Safety, Subcommittee 4, USA)
Do Microwaves Induce Free Radicals in Food or Tissues?

John Osepchuk\textsuperscript{1}, Robert Schiffmann\textsuperscript{2} and C-K. Chou\textsuperscript{3}

\textsuperscript{1} Full Spectrum Consulting
\textsuperscript{2} R.F. Schiffmann Associates, Inc.
\textsuperscript{3} Motorola Solutions, Inc.

USA
Conclusions

There is no truth to the rumor that microwaves cause free radicals and cancer, either in food by cooking or by low-level exposure of humans to such energy. This conclusion is supported by governments, professional organizations and science. The burden of proof remains on claims to the otherwise.
Active Implantable Medical Devices and Electromagnetic Compatibility

Veronica Ivans, BSEE
IMD Standards, LLC

C-K Chou, PhD
Motorola Solutions, Inc.

PIERS 2013, Taipei
March 26, 2013
Summary

Control of EMI for AIMDs involves:

- Body tissues
- Shielding
- Passive electronic filtering
- Feedthrough filters
- Software features
- Compliance to existing EMC standards
- Other mitigating features, all working together
Summary

- Emitting equipment emission limits are addressed by human safety exposure standards.
- These standards are based on average power and short-term biological effects; as a result:
  - Emitters may produce pulsed signals where peak power greatly exceeds pacemaker/ICD capability of rejecting noise.
  - Don’t ensure electromagnetic compatibility.
- Emitter manufacturers encouraged to pay attention to the immunity of implantable devices and work with the AIMD manufacturers.
Update of IEEE C95.1
Exposure Standard Revision

C-K. Chou*, J.P. Reilly, R. Kavet, B.J. Klauenberg, M. Ziskin,
A. Thansandote, T. Dovan, R.A. Tell, K. Gettman,
R. Bodemann, and R.C. Petersen

International Committee on Electromagnetic Safety, TC95
IEEE
Piscataway, NJ, USA

*A report of the Editorial Working Group
Speaking as individuals and not for the IEEE
Conclusions

- C95.6-2002 and C95.1-2005 standards are developed to protect against potential established adverse health effects.
- At low frequencies below 5 MHz, minimizes effects associated with electrostimulation.
- 100 kHz to 300 GHz, protects against effects associated with heating.
- Combination of C95.6 and C95.1 is in progress
- Terminology changes to clarify and convey more obvious meaning to these terms.
- ICES considers harmonization with ICNIRP and the proposed European Union Directive important with an ultimate goal of internationally-harmonized EMF exposure criteria.
Impact of Planning Based Restrictions on Operation of Mobile Networks

Jack Rowley

GSM Association

PIERS 2013 Taipei
Progress In Electromagnetics Research Symposium
March 25–28, 2013
Summary

- Planning based exclusion zones are unworkable and may actually have an adverse effect on community development both in regard to access to mobile services and the ability to locate new community facilities.

- Further analysis could consider direct quality of service impacts.

- WHO recommendations on limits, policy and communication should be the basis for government responses.
Thermal Dosimetry and Thermal Dynamics of In Vitro RF Bioassays

Medium Geometry: The Dominant Factor of In Vitro Exposure

Quirino Balzano  Giorgi Bit-Babik  Asher R. Sheppard

PIERS 2013, March 24-28, Taipei, ROC
CONCLUSION

• DURING MAINLY H-EXPOSURE MEDIUM IS LOOP ANTENNA

• RF CURRENTS AND SAR PATTERNS DEPEND ON GEOMETRY (SHAPE AND VOLUME) OF MEDIUM

• THERMAL DYNAMICAL EFFECTS CAN CAUSE SUSTANTIAL DIFFERENCE IN THE BIOENVIRONMENTS OF EXPOSED AND UNEXPOSED CELL SAMPLES
Interesting issues of mobile phones and base stations in Taiwan

Ji-Shing Lin
Office of Board of S&T, Cabinet, TAIWAN
Conclusion I

• The blind leading the blind

• Passion over science (scaremonger)
Conclusion II

• “State of Fear”
  • Cancers and others attributed to EMF
  • EHS prevalence 13.5%

• “BioInitiative” hurts
Conclusion III

- Wrong perceptions poisoning Taiwan
- **Bless Taiwan** (and the World)
Visist NCC of Taiwan (3/25/2013)

• C-K. Chou and Jack Rowley of GSMA accompanied by Dr. JS Lin of Taiwan to visit National Communications Commission.

• Had a good meeting with Vice-Chairman Commissioner Yu and Commissioner Wei, and three NCC staff
International Committee on Electromagnetic Safety

Secretary’s Report

TC95 Meeting

8 June 2013

Thessaloniki, Greece

R Petersen
ICES – Administrative

Policies and Procedures (P&P):

- Defines organizational structure (SCC-39)
- Based on “SA Baseline P&Ps for Type 2 SCCs” (with deviations)
- Revision of 2007 P&Ps accepted by SASB, December 2012
- Working Group (SC) P&Ps are now Required
- WG P&Ps submitted to SASB AudCom for review at June Meeting


- Accepted by SASB, December 2012

Interpretation requests:

- No outstanding interpretation requests
**ICES TC95 Standards: Status**

- **C95.1-2005**: (Safety levels, 3 kHz – 300 GHz)
  - Approved 2005; published 2006
  - PAR for revision – approved (June 2010)
  - Revision will incorporate C95.6 (Safety levels, 0 Hz to 3 kHz)

- **PC95.1a**: (Safety levels, 3 kHz – 300 GHz)
  - Published May 2010
  - Amendment 1 (sets ceiling values for induced and contact current)

- **C95.2-1999**: (RF energy and current flow symbols)
  - Reaffirmed 2005
  - PAR for Revision approved (November 2010)
ICES TC95 Standards: Status

- **C95.3-2002**: (RF measurements and computation: 100 kHz to 300 GHz)
  - Reaffirmed 2008
  - Revision will incorporate C95.3.1
- **PC95.3.1**: (Measurements and computation: 0 Hz to 100 kHz)
  - Incorporates IEEE 1460
  - Published May 2010
- **C95.4-2002**: (Safe distances from antennas during blasting operations)
  - Reaffirmed 2008
**ICES TC95 Standards: Status**

- **C95.6-2002**: (Safety levels - 0 to 3 kHz)
  - Reaffirmed 2007
  - Will be incorporated into C95.1 (Safety levels, 3 kHz to 300 GHz)

- **C95.7-2005**: (RF safety programs)
  - PAR for Revision approved (November 2010)
  - SC balloting completed - ready for sponsor ballot

- **1460-1996**: (Measurement of quasi-static electric and magnetic fields)
  - Reaffirmed 2008
  - Incorporated into C95.3.1
  - Action - Withdraw (2013)
New Project Authorization Requests (PARs)

- **PC95.1**: (Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic and Electromagnetic Fields, 0 Hz to 300 GHz)
  - PAR approved June 2010
  - Revision and merge of C95.1-2005 and C95.6-2002 into a single standard

- **PC95.1-2345**: (Standard for the Evaluation and Control of Personnel Exposure to Electric, Magnetic and Electromagnetic Fields, 0 Hz to 300 GHz)
  - PAR approved September 2009
  - Civil standard for consideration as NATO STANAG 2345 replacement
  - SC balloting completed
  - Submitted for Sponsor ballot 1 June 2013
New Project Authorization Requests (PARs)

- **PC95.3**: (Recommended Practice for Measurements and Computations of Electric, Magnetic and Electromagnetic Fields With Respect to Human Exposure to Such Fields, 0 Hz-300 GHz)
  - PAR approved February 2012
  - Revision and merge of C95.3-2002 and C95.3.1-2010 into a single standard
Changes: Reaffirmation/Stabilization

Effective Jan 1, 2012:

- There will be no new reaffirmation or stabilization ballots
  - The only actions allowed by Sponsors will be:
    - Revision
    - Amendment/Corrigendum
    - Withdrawal
  - Standards will now have a 10 year maintenance cycle (i.e., extended from 5 years to 10 years after the last date of approval or maintenance action)
  - The status for a standard will be either active or inactive
  - All standards must have a revision approved by the IEEE-SASB prior to the close of Year 10 in order to remain active
  - Any standard not approved as a revision will become inactive after year 10
**Changes: Inactive Standards**

**Categories of Inactive Standards:**

- **Inactive - superseded:** These standards have been replaced with a revised version of the standard.

- **Inactive - reserved:** These standards are removed from active status through an administrative process for standards that have not undergone a revision process within 10 years.

- **Inactive - withdrawn (valid for standards categorized after 1 January 2012):** These standards have been removed from active status through a ballot where the standard is made inactive as a consensus decision of the balloting group.
Changes: Revisions

Revisions:

- A revision ballot may result in:
  - Changes to the standard
  - Changes to only the references or bibliography
  - No changes at all

- In the event that no changes are made, the standard will retain its designation (i.e., the year will not change).

- The title page will reflect the fact that a maintenance action occurred but no changes were made.

- This will keep the standard active for another 10 years
### SCC39 Standards: Expiration Dates

<table>
<thead>
<tr>
<th>Number</th>
<th>Year</th>
<th>Expiration Date</th>
<th>Approval Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1460</td>
<td>1996</td>
<td>12/31/2018</td>
<td>12/10/1996</td>
</tr>
<tr>
<td>1528</td>
<td>2003</td>
<td>12/31/2018</td>
<td>06/12/2003</td>
</tr>
<tr>
<td>1528a</td>
<td>2005</td>
<td>12/31/2018</td>
<td>09/22/2005</td>
</tr>
<tr>
<td>C95.1</td>
<td>2005</td>
<td>12/31/2018</td>
<td>10/03/2005</td>
</tr>
<tr>
<td>C95.1a</td>
<td>2010</td>
<td>02/02/2020</td>
<td>02/02/2010</td>
</tr>
<tr>
<td>C95.2</td>
<td>1999</td>
<td>12/31/2018</td>
<td>09/16/1999</td>
</tr>
<tr>
<td>C95.3</td>
<td>2002</td>
<td>12/31/2018</td>
<td>12/11/2002</td>
</tr>
<tr>
<td>C95.3.1</td>
<td>2010</td>
<td>03/25/2020</td>
<td>03/25/2010</td>
</tr>
<tr>
<td>C95.6</td>
<td>2002</td>
<td>12/31/2018</td>
<td>09/12/2002</td>
</tr>
<tr>
<td>C95.7</td>
<td>2005</td>
<td>12/31/2018</td>
<td>09/22/2005</td>
</tr>
</tbody>
</table>
Changes: Interpretations

Elimination of Interpretations:

- The IEEE-SA Standards Board approved a proposal to eliminate issuing interpretations in June 2011

Rationale:

- Inefficient and a risk
  - Interpretation responses made in an attempt to clarify ambiguous text to be derived from a process that does not inform all materially interested parties of the activity
  - Does not require consensus to be achieved through the Sponsor balloting process
Solution:

- More sensible to simply funnel comments on standards to Sponsors for handling
  - Any document changes would appear in a revision amendment/corrigendum
  - All require PARs - an open process & consensus through balloting
- Therefore interpretations as discrete documents are discontinued
Changes: Individual Experts

**Individual Expert:**

- Members of the working groups who are not SA members but contributed significantly to the development of a standard could participate in sponsor ballots if approved by the SASB as “individual experts”

- **Individual Expert** category has been eliminated

- Now, only IEEE-SA Members or individuals who pay a fee are permitted to vote on IEEE sponsor ballots

- TC95 SC/WGs follow IEEE sponsor balloting procedures

- **TC95 members and members of the TC95 SCs and WGs who are not IEEE-SA members and desire to vote on a standard should join the WG ballot groups**
Secretary’s Report

Thank You
Treasurer’s Report

TC95 Meeting
8 June 2013
Thessaloniki, Greece
R Petersen
**Financial Statement: 1/1/13—5/31/13**

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Balance (01/01/13):</strong></td>
<td>$10,496.68</td>
<td></td>
</tr>
<tr>
<td><strong>Deposits:</strong></td>
<td>$5,279.73</td>
<td>Jan 13 Meeting (Registrations)</td>
</tr>
<tr>
<td><strong>Disbursements:</strong></td>
<td>$849.21</td>
<td>Jan 13 Meeting (Badges, Refreshments)</td>
</tr>
<tr>
<td></td>
<td>$2,520.00</td>
<td>Website Maintenance</td>
</tr>
<tr>
<td><strong>Interest:</strong></td>
<td>$13.28</td>
<td></td>
</tr>
<tr>
<td><strong>Balance (5/31/13):</strong></td>
<td>$12,420.48</td>
<td></td>
</tr>
</tbody>
</table>
IEEE ICES TC95 members listed in ICES website. (as of May 2013)

<table>
<thead>
<tr>
<th>Max Ammann</th>
<th>Ken Joyner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitas Anderson</td>
<td>Wolfgang Kainz</td>
</tr>
<tr>
<td>Quirino Balzano</td>
<td>Shaiela Kandel</td>
</tr>
<tr>
<td>Dave Baron</td>
<td>Efthymios Karabetos</td>
</tr>
<tr>
<td>Howard Bassen</td>
<td>Robert Kavet</td>
</tr>
<tr>
<td>John Bergeron</td>
<td>Ae-Kyoung Lee</td>
</tr>
<tr>
<td>Ralf Bodemann</td>
<td>Byung Chan Kim</td>
</tr>
<tr>
<td>Aviva Brecher</td>
<td>Niels Kuster</td>
</tr>
<tr>
<td>Ian Brooker</td>
<td>Rajat Mathur</td>
</tr>
<tr>
<td>Jerrold Bushberg</td>
<td>Hiroaki Miyagi</td>
</tr>
<tr>
<td>Konstantinos Chalkiotis</td>
<td>Michael R. Murphy</td>
</tr>
<tr>
<td>C-K Chou</td>
<td>Hughes Nappert</td>
</tr>
<tr>
<td>Selçuk Çömlekçi</td>
<td>Bob Needy</td>
</tr>
<tr>
<td>Rodney Croft</td>
<td>Kwan-Hoong Ng</td>
</tr>
<tr>
<td>John D’Andrea</td>
<td>John Osepchuk</td>
</tr>
<tr>
<td>Rene De Seze</td>
<td>Ron Petersen</td>
</tr>
<tr>
<td>David Dini</td>
<td>Paolo Ravazzani</td>
</tr>
<tr>
<td>Mark Douglas</td>
<td>Theodoros Samaras</td>
</tr>
<tr>
<td>Thanh Dovan</td>
<td>Devashish Shrivastava</td>
</tr>
<tr>
<td>Kenneth Foster</td>
<td>Art Thansandote</td>
</tr>
<tr>
<td>Josette Gallant</td>
<td>György Thuróczy</td>
</tr>
<tr>
<td>Kenneth Gettman</td>
<td>Arthur G. Varanelli</td>
</tr>
<tr>
<td>David George</td>
<td>Robert Weller</td>
</tr>
<tr>
<td>Donald L. Haes</td>
<td>Marvin Wessel</td>
</tr>
<tr>
<td>Ray Harmon</td>
<td>Kenichi Yamazaki</td>
</tr>
<tr>
<td>Jim Hatfield</td>
<td>Donald Zipse</td>
</tr>
<tr>
<td>Akimasa Hirata</td>
<td>Marvin Ziskin</td>
</tr>
<tr>
<td>Michel Israel</td>
<td></td>
</tr>
<tr>
<td>Robert Johnson</td>
<td></td>
</tr>
<tr>
<td>Christine Jones</td>
<td></td>
</tr>
</tbody>
</table>
RF Safety Report & Order

ET Docket No. 03-137
May 24, 2013

Robert Weller
U.S. Federal Communications Commission
Office of Engineering & Technology

The opinions expressed are my own, and do not necessarily reflect the views of the FCC or any of its Commissioners.
Exposure Policy Overview

Exemption:
Simple calculation to establish whether an RF source falls into the category where no further compliance determination is necessary.

Evaluation:
Determination of potential exposure levels from an RF source to ensure compliance by calculation, measurement, or computational modeling.

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

- **Evaluation** - determination of potential exposure levels by calculation, measurement, or computational modeling

- **Mitigation** – post-evaluation procedures to ensure exposure limits are not exceeded, such as training, labels, signs, and barriers
In the Order ... (cont’d)

**Evaluation**
- SAR for fixed sources
  - compliance can be demonstrated either by SAR or MPE evaluation. SAR is primary.
- No more OET-65C
- Outer ear (pinna) is treated as an extremity

**Mitigation**
- Occupational exposures
  - clarification of information and training requirements
- Collocations
  - clarification of compliance responsibility
- Other
SAR Evaluation for Fixed Sources

- Below 6 GHz (and above 100 kHz)
- No change to SAR requirement for portables
- Compliance with both localized and whole-body SAR required when source <20 centimeters from body.
- Rules now specify whole-body and partial-body exposure limits for SAR and allow evaluation of SAR in lieu of power density or field strength for all fixed and mobile RF sources below 6 GHz
- Below 6 GHz, SAR is primary to MPE at any distance
SAR Evaluation for Fixed Sources (cont’d)

- Evaluation required in all operating configurations and exposure conditions, considering both whole- and partial-body limits and both near- and far-field situations.

- *post factum* SAR evaluation not allowed as a response to enforcement action

- Benefit: SAR evaluation costs apply only once to each unique device or antenna configuration
  
  - Allows for manufacturer or enterprise-wide demonstration of intrinsic compliance (Smart meters, DAS nodes, etc.)
OET-65, Supplement C Eliminated

- CFR references changed to OET Laboratory Knowledge Database (KDB)
  - Benefit: more current guidance and policies on evaluation procedures
  - Eliminates ambiguity and conflict between KDB and Supplement C
  - Supporting documentation (e.g., parameters, models, comparisons with measurement) of computational modeling now required in all cases
The outer ear (pinna) now included on the list of exceptions from local SAR limits
- Tissues in pinna are similar to extremities

Codifies present practice

For pinna, SAR limit = 4 W/kg (10 g cube of tissue)
- 20 W/kg (10 g cube) for occupational exposures

For brain, etc., 1.6 W/kg (1 g cube of tissue) continues to apply
- 8 W/kg (1 g cube) for occupational exposures
Labeling of Occupational Devices

- External labels now required on occupational devices
  - Label design not specified
  - Label can be virtual (screen flash on start-up)
  - Label can refer to manual for additional info
  - Includes ham radios

- Coordination of training requirements with end-users/user groups is encouraged.
Discussion Concepts for Occupational Device Labels

**Caution**

<table>
<thead>
<tr>
<th>Trade Name</th>
<th>Model Number</th>
<th>FCC ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trade Name</td>
<td>Model Number</td>
<td>FCC ID</td>
</tr>
</tbody>
</table>

Restricted to occupational use to comply with exposure limits. Remain at least ___ inches (___ cm) away and do not transmit for more than ___ minutes in a 6 minute period. Never use this device without proper training. Refer to manual for proper operating power, time, and separation distance.

**Notice**

<table>
<thead>
<tr>
<th>Trade Name</th>
<th>Model Number</th>
<th>FCC ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trade Name</td>
<td>Model Number</td>
<td>FCC ID</td>
</tr>
</tbody>
</table>

Restricted to occupational use to comply with exposure limits. Remain at least ___ inches (___ cm) away and do not transmit for more than ___ minutes in a 6 minute period. See manual.
Information and Training

- Occupational users must be “fully aware” and able to “exercise control” over exposures

- Fully aware: received written and/or orally-communicated information concerning the potential for RF exposure and received training regarding appropriate work practices
  - Transiently-exposed individuals exempt from training

- Exercise control: able to reduce or avoid exposure by administrative or engineering controls

- Transient individuals do not include third-party workers
Collocations

- FCC continues to encourage all site occupants, owners, leasers, and managers to cooperate and share information about power and other operating characteristics, in order to achieve accurate representations of the RF environment.

- All licensees that exceed 5% of the RF exposure limit at any non-compliant location are jointly and severally responsible, and the Commission may impose forfeiture liability on all such licensees.
Labeling for Fixed Consumer Transmitters

- Present requirements for professional installation or device design are adequate (no evidence of non-compliance with the exposure limits)

- Manufacturers and licensees should continue to provide information in user manuals regarding proper and safe installation

- Labeling cannot be used to justify consumer device exposure at occupational levels.
Other items

- Allow either measurement or computation of SAR in MedRadio service (implanted and body-worn devices)

- **Reminder**: regardless of whether a site is exempt from routine evaluation, licensees are required to ensure that existing sites are in compliance with our exposure limits.

- Commission may take enforcement action against licensees that do not comply with the exposure limits, regardless of whether their transmitters were “categorically excluded” or “exempt” from routine evaluation in the past.
RF Safety Further Notice

ET Docket No. 03-137
May 24, 2013

Martin Doczkat
U.S. Federal Communications Commission
Office of Engineering & Technology

The opinions expressed are my own, and do not necessarily reflect the views of the FCC or any of its Commissioners.
Exposure Policy Overview

Low Power
Large Distance

Exemption:
Simple calculation to establish whether an RF source falls into the category where no further compliance determination is necessary.

Evaluation:
Determination of potential exposure levels from an RF source to ensure compliance by calculation, measurement, or computational modeling.

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

High Power
Small Distance
In the *Further Notice* ...

- **Exemption**
  - Power and Distance Criteria to Streamline Determination of Compliance for all RF Sources

- **Evaluation of Portable Devices**
  - Measurement above 6 GHz
  - Generalized computational modeling
  - Remove specific technical references

- **Mitigation at Fixed transmitters**
  - Signs and barriers
  - Definition of transient exposure
1. Exemption

- Objective: unify and derive exemption criteria based on power and distance for fixed, mobile, and portable services, including implants
- Existing Fixed/Mobile Transmitter Exclusions
- Consistent treatment of all services
- Blanket exemption
- MPE-Based for Single Transmitters
- SAR-Based for Single Transmitters
- Multiple Transmitter Summation
Existing Fixed/ Mobile Transmitter Exclusions

- Existing exclusions do not always ensure compliance with exposure limits
  - Example: Rooftop transmitters less than 2 kW ERP are excluded from routine evaluation, regardless of access

- Original Notice proposals patch Table in 1.1307(b)

- Existing mobile exclusion assumed no reflection and frequencies only above 800 MHz

- Table excludes potentially non-compliant transmitters by not listing service
Consistent Treatment of All Services

- **Evaluation:** determine compliance with exposure limits by calculation or measurement of field strength or SAR
- **Exemption:** based on power and distance, determine that evaluation is unnecessary
- Currently, routine evaluations are required for specific subparts meeting certain criteria
  - See Table 1 in § 1.1307(b)(1) and text in (b)(2)
- **General exemption criteria are proposed to apply to all subparts authorizing RF sources**
Blanket 1 mW Average Available Power Exemption

- Proposed for any single RF source
- Independent of frequency
  - 100 kHz to 100 GHz
- 6 GHz break in justification
  - SAR limit 1.6 mW/g at \( \leq 6 \text{ GHz} \)
    - Average over 1 g
  - MPE limit 1 mW/cm\(^2\) at > 6 GHz
    - Average over 1 cm\(^2\)
- Most useful for low power and/or low duty cycle devices such as medical implants
- Multiple transmitter, 2 cm separation or sum
MPE-Based Exemption for Single Fixed, Mobile, and Portable RF Sources

<table>
<thead>
<tr>
<th>Transmitter Frequency (MHz)</th>
<th>Threshold ERP (watts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regardless of ERP, evaluation is required if the separation distance from the radiating structure, R, is less than (\frac{\lambda}{2\pi}), where (\lambda) is the free-space operating wavelength, unless the available maximum time-averaged power is less than one milliwatt. In addition, evaluation is required if the ERP in watts is greater than the value given by the formula below for the appropriate frequency, (f), in MHz at the separation distance, R, in meters.</td>
<td></td>
</tr>
<tr>
<td>0.3 – 1.34</td>
<td>(ERP \geq 1,920 R^2)</td>
</tr>
<tr>
<td>1.34 – 30</td>
<td>(ERP \geq 3,450 R^2/f^2)</td>
</tr>
<tr>
<td>30 – 300</td>
<td>(ERP \geq 3.83 R^2)</td>
</tr>
<tr>
<td>300 – 1,500</td>
<td>(ERP \geq 0.0128 R^2f)</td>
</tr>
<tr>
<td>1,500 – 100,000</td>
<td>(ERP \geq 19.2 R^2)</td>
</tr>
</tbody>
</table>
MPE-Based Exemption Definition

- **Basis:** public exposure limit, far-field in the main beam, one perfect reflection
- **Evaluation** is proposed to be required if the separation distance is less than $\frac{\lambda}{2\pi}$
- **Maximum time-averaged power** is largest net power accepted by the antenna as averaged over any 30 minute time period and is used with maximum gain to determine ERP
- **Separation distance** is defined as the minimum distance in any direction from any part of the radiating structure of a transmitting antenna to a human body
d = \frac{\lambda}{2\pi}
# SAR-Based Exemption for Single Fixed, Mobile, and Portable RF Sources

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>0.3</th>
<th>0.45</th>
<th>0.835</th>
<th>0.9</th>
<th>1.45</th>
<th>1.8</th>
<th>1.9</th>
<th>2.45</th>
<th>3</th>
<th>5.2</th>
<th>5.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (cm)</td>
<td>0.5</td>
<td>1</td>
<td>1.5</td>
<td>2</td>
<td>2.5</td>
<td>5</td>
<td>7</td>
<td>10</td>
<td>12.5</td>
<td>15</td>
<td>17.5</td>
</tr>
<tr>
<td>0.5</td>
<td>39</td>
<td>65</td>
<td>88</td>
<td>110</td>
<td>130</td>
<td>220</td>
<td>280</td>
<td>360</td>
<td>430</td>
<td>490</td>
<td>550</td>
</tr>
<tr>
<td>1.0</td>
<td>22</td>
<td>44</td>
<td>67</td>
<td>89</td>
<td>110</td>
<td>230</td>
<td>320</td>
<td>460</td>
<td>570</td>
<td>690</td>
<td>800</td>
</tr>
<tr>
<td>1.5</td>
<td>9.2</td>
<td>25</td>
<td>44</td>
<td>66</td>
<td>90</td>
<td>240</td>
<td>390</td>
<td>640</td>
<td>880</td>
<td>1100</td>
<td>1400</td>
</tr>
<tr>
<td>2.0</td>
<td>8.3</td>
<td>23</td>
<td>42</td>
<td>63</td>
<td>88</td>
<td>240</td>
<td>400</td>
<td>670</td>
<td>920</td>
<td>1200</td>
<td>1500</td>
</tr>
<tr>
<td>2.5</td>
<td>4.3</td>
<td>15</td>
<td>30</td>
<td>50</td>
<td>74</td>
<td>250</td>
<td>460</td>
<td>870</td>
<td>1300</td>
<td>1800</td>
<td>2300</td>
</tr>
<tr>
<td>3.0</td>
<td>3.5</td>
<td>13</td>
<td>26</td>
<td>45</td>
<td>67</td>
<td>240</td>
<td>450</td>
<td>860</td>
<td>1300</td>
<td>1800</td>
<td>2400</td>
</tr>
<tr>
<td>3.4</td>
<td>3.4</td>
<td>12</td>
<td>26</td>
<td>44</td>
<td>66</td>
<td>240</td>
<td>440</td>
<td>850</td>
<td>1300</td>
<td>1800</td>
<td>2400</td>
</tr>
<tr>
<td>2.7</td>
<td>2.7</td>
<td>10</td>
<td>22</td>
<td>38</td>
<td>59</td>
<td>220</td>
<td>420</td>
<td>820</td>
<td>1300</td>
<td>1800</td>
<td>2400</td>
</tr>
<tr>
<td>2.3</td>
<td>2.3</td>
<td>9.0</td>
<td>20</td>
<td>35</td>
<td>53</td>
<td>210</td>
<td>400</td>
<td>790</td>
<td>1200</td>
<td>1700</td>
<td>2400</td>
</tr>
<tr>
<td>1.5</td>
<td>1.5</td>
<td>6.3</td>
<td>15</td>
<td>26</td>
<td>42</td>
<td>170</td>
<td>350</td>
<td>730</td>
<td>1200</td>
<td>1700</td>
<td>2300</td>
</tr>
<tr>
<td>1.4</td>
<td>1.4</td>
<td>5.9</td>
<td>14</td>
<td>25</td>
<td>40</td>
<td>170</td>
<td>340</td>
<td>720</td>
<td>1100</td>
<td>1700</td>
<td>2300</td>
</tr>
</tbody>
</table>

Evaluation is required if either matched conducted or effective radiated power (ERP) is greater than:

\[ P_{th} \text{ (mW)} = ERP_{20 \text{ cm}} \left( \frac{d}{20 \text{ cm}} \right)^x \]

where: \( x = \log_{10} \left( \frac{60}{ERP_{20 \text{ cm}} \sqrt{f}} \right) \) and

\[ ERP_{20 \text{ cm}} \text{ (mW)} = \begin{cases} 2040f \\ 3060 \end{cases} \quad \begin{cases} 0.3 \text{ GHz} \leq f < 1.5 \text{ GHz} \\ 1.5 \text{ GHz} \leq f \leq 6 \text{ GHz} \end{cases} \]

Valid only at distances from 0.5 cm to 20 cm and frequencies from 0.3 GHz to 6 GHz. However, values obtained in the formula at exactly 20 cm may be used between 20 and 40 cm.
SAR-Based Exemption Definition

- Single transmitters operating between 300 MHz and 6 GHz with a separation distance between 0.5 and 40 cm
- Basis: $\lambda/2$ dipole SAR in planar absorber at 0.5 to 20 cm, without reflection
- Continuity with MPE-based exemption at 40 cm so flat from 20 to 40 cm to transition to single reflection
- MPE-based exemption is also valid at greater than $\lambda/2\pi$, but more restrictive
- Least restrictive valid exemption may be used
Exemption Criteria Domains

- **MPE-Based Exemption Criteria**
  - Frequency: 0.3 to 6 GHz
  - Separation Distance: 0.5 to 40 cm

- **SAR-Based Exemption Criteria**
  - Frequency: 100 GHz
  - Separation Distance: N/2π

**Evaluation Required**

**Frequency**
- 300 kHz to 100 GHz
Exemptions for Multiple Transmitters

Summation not used: exposure from fixed sources is independent of mobile/portable sources

- Fixed
- Portable
- Implanted
- Mobile

Environmental Whole-Body Exposure
Personal Localized Exposure

Summation required for multiple transmitters in a single device
Summation Principles for Exemption of Multiple Transmitters

- Summation for RF sources without definable physical relationships is not required.
- Not necessary to sum fixed transmitters with mobile or portable device transmitters.
- Summation of mobile plus portable is proposed to be required for a single device but not for different devices.
- Sum transmitters which operate within the same averaging period.
- Both MPE and SAR based exemptions may be applied to fixed, mobile, or portable transmitters where valid.
Multiple Portable/ Mobile in a Single Device

Evaluation is required if:

\[
\sum_{i=1}^{a} \frac{P_i}{P_{th,i}} + \sum_{j=1}^{b} \frac{SAR_j}{1.6 \ W/kg} + \sum_{k=1}^{c} \frac{ERP_k}{ERP_{th,k}} \geq 1
\]

Where

- \( a \) = number of mobile or portable RF sources using SAR-based exemption.
- \( b \) = number of existing mobile or portable RF sources with known SAR.
- \( c \) = number of mobile or portable RF sources using ERP.
- \( P_i \) = greater of available power or ERP for RF source \( i \) between 0.5 cm and 20 cm.
- \( P_{th,i} \) = SAR-based threshold power for RF source \( i \).
- \( SAR_j \) = maximum SAR reported from the \( j^{th} \) mobile or portable RF source.
- \( ERP_k \) = ERP of mobile or portable RF source \( k \).
- \( ERP_{th,k} \) = exemption threshold ERP for RF source \( k \), either 20 cm to 40 cm if using SAR-based exemption or \( > \lambda/2\pi \) if using MPE-based exemption.
Multiple Fixed Transmitters

Evaluation is required if:

$$\sum_{i=1}^{a} \frac{P_i}{P_{th,i}} + \frac{\sum_{j=1}^{b} SAR_j}{1.6 \text{ W/kg}} + \frac{\sum_{k=1}^{c} ERP_k}{ERP_{th,k}} + \text{AEQ} \geq 1$$

Where

- \(a\) = number of fixed RF sources using SAR-based exemption.
- \(b\) = number of existing fixed RF sources with known SAR.
- \(c\) = number of fixed RF sources using MPE-based exemption.
- \(P_i\) = greater of available power or ERP for RF source \(i\) between 0.5 cm and 20 cm.
- \(P_{th,i}\) = SAR-based threshold power for RF source \(i\).
- \(SAR_j\) = maximum SAR reported from the \(j^{th}\) fixed RF source.
- \(ERP_k\) = ERP of RF source \(k\).
- \(ERP_{th,k}\) = exemption threshold ERP for RF source \(k\), either 20 cm to 40 cm if using SAR-based exemption or \(\lambda/2\pi\) if using MPE-based exemption.
- \(\text{AEQ}\) = ambient exposure quotient (AEQ) for the general population/uncontrolled Maximum Permissible Exposure (MPE) limit from an existing evaluation at the site of exposure from fixed sources. AEQ is the sum of the quotient(s) of each ambient power density or field strength squared and their respective MPE(s) for a particular frequency, also commonly referred to as “fraction of standard.” Note that the AEQ is due to RF sources not included in the ERP summations.
2. Evaluation

- Evaluation: computation and measurement for non-exempt transmitters
- Portable / implanted devices (update details)
Evaluation for Portable Devices

- Remove unnecessary details from rules
  - Delete minimum 5 cm measurement distance above 6 GHz (§ 2.1093(d))
    - No longer a practical limitation
    - Allows SAR discontinuity at 6 GHz
  - SAR computational methods for implants
    - Remove specification of FDTD
    - Propose “computational modeling” as in § 2.1093(d)(3)
3. Mitigation

- Fixed Transmitters
  - Definition of transient exposure
  - Signs and barriers
Mitigation at Fixed Sites

- Definition of transient exposure with respect to averaging time
  - General Population/“Controlled”
    - Not to exceed general population limit with time averaging
    - Not to exceed the continuous occupational limit at any time

- Signs, barriers, and other RF safety program elements
  - Comments received requesting more guidance
  - Principally reference IEEE C95.7 and additional guidance from NCRP and NAB, with significant exceptions
  - Propose updating guidance in 1986 Public Notice
  - Consider on a case-by-case basis barrier practicality and accessibility (rooftops, natural features, roads, remoteness, etc.)
    - OET65 App. B)
NOTE: where potential for immediate and serious injury, regardless of category

Training required to keep within exposure limits (PPE, time avg., lockout/tagout) (no transient)

Training required (unless transient)

Restrictive barriers (no training necessary)

Training required
Proposed Sign Content

- RF exposure warning signs are proposed to include at least the following components:
  - Appropriate signal word and associated color (“DANGER,” “WARNING,” “CAUTION,” or “NOTICE”)  
  - RF energy advisory symbol (Figure A.3 of C95.2-1999)
  - An explanation of the hazard (exposure to RF energy)
  - How to avoid the hazard (e.g., “Do not climb tower while antennas are energized”)
  - Contact information

- Optional “INFORMATION” sign where appropriate
Sign Content - Examples

SW = Signal Word – required (IEEE)

- **DANGER**
- **WARNING**
- **CAUTION**
- **NOTICE**

S = Symbol – required: **NOTICE** = 📣

**CAUTION**, **WARNING**, **DANGER** = 📣

T = Text – examples from NAB Engineering Handbook:

- **DANGER** = “DO NOT ENTER. THIS TOWER IS ENERGIZED AT HIGH RF VOLTAGE.”
- **WARNING** = “DO NOT CLIMB TOWER WHILE ANTENNAS ARE ENERGIZED. OBSERVE LOCKOUT/TAGOUT PROCEDURES.”
- **CAUTION** = “DO NOT ENTER WITHOUT AUTHORIZATION. AREAS OF THIS SITE MAY EXCEED FCC LIMITS.”
- **NOTICE** = “RADIOFREQUENCY FIELDS BEYOND THIS POINT MAY EXCEED FCC GUIDELINES FOR THE GENERAL PUBLIC.”

CONTACT TOWER/SITE OWNER/MANAGER AT ________ FOR FURTHER INFORMATION.
Recommended INFORMATION Sign Content

While not required, recommend:

- Key word and color
- Explanation of safety precaution
- Contact information for each licensee
- Obey all postings and boundaries
- (keep-back distance and symbol not recommended - purpose of NOTICE sign)
- Language other than English depending on locality (due to lack of symbol)

Adapted from 2002 NCRP Letter - Figure 8
ET Docket Nos. 03-137 & 13-84

Color Key and Signs at Exposure Boundaries in Accord with IEEE Std C95.7-2005

**NOTICE**
- General Population Limit for Continuous Exposure
  - e.g., Personal Monitor, Contact Information

**CAUTION**
- Occupational Limit for Continuous Exposure
  - e.g., Protective Suit, Time Averaging

**WARNING**
- 10 X Occupational Limit for Continuous Exposure
  - e.g., Reduce Power
Recap on *Further Notice*

- **Exemption**
  - Power and Distance Criteria to Streamline Determination of Compliance for all RF Sources

- **Evaluation of Portable Devices**
  - Measurement above 6 GHz
  - Generalized computational modeling
  - Remove specific technical references

- **Mitigation at Fixed transmitters**
  - Signs and barriers
  - Definition of transient exposure
RF Safety Notice of Inquiry

ET Docket No. 13-84
May 24, 2013

Ed Mantiply
U.S. Federal Communications Commission
Office of Engineering & Technology

The opinions expressed are my own, and do not necessarily reflect the views of the FCC or any of its Commissioners.
Themes of Inquiry

- Exposure Limits
- Agencies and International Input
- Exposure Reduction
- Science-Based Examination
- Evaluation Procedures
Exposure Limits

- FCC Exposure Limits Adopted in 1996
  Based on IEEE and NCRP
- ICNIRP 1998 and IEEE 2006
  - Same SAR Basis so Confident
  - Lots of Differences in the Details
  - Frequencies below 10 MHz
- Update or Stay the Same?
Exposure Limits (Technical)

- Localized SAR Limits
- Power Density Averaging Area
- Averaging Time
- Peak Pulsed Fields
- Contact Currents
- Frequency Range
- Conductive Implants
Exposure Reduction

- **WHO**
  - Model Legislation
  - Environmental Health Criteria

- **IARC**
  - Classification of RF as Possible Carcinogen

- **Consumer Information**

- **Exposure Reduction Policies**
Consumer Information

- Lists Existing Information
- Infrastructure with Low Exposure Generates most Concern
- Request Suggestions
- SAR Availability and and Relevance
Exposure Reduction Policies

- “Bright-Line Rule” Incorporates Safety Factor
- “Prudent Avoidance” – Further Reduce Incidental Exposure at Modest Expense
- Devices versus Infrastructure
- Trade-Offs
- Effect of DAS on exposure?
Evaluation Procedures

- Determination of Compliance by Measurement or Computation
- Guided by SAR Primacy and GEP
  - Non-Regulatory Methods Development
  - Computation versus Measurement
  - Reliability and Feasibility
- FCC and IEC Guidance on Fixed Source Evaluation
Separation Distance

- Normal or Minimum
- 20 cm for Fixed MPE Evaluation
- 2.5 cm Portable Body-Worn versus Normal Use
What’s Next

- Comments Due: Fed. Reg. + 90 Days
- Final *Order for Further Notice*
- *Inquiry* does not Obligate Commission
- Possible: Report, Expert Group, NPRM
References

- **FCC 13-39, In the Matter of:**
  - ET Docket No. 03-137
    - Proposed Changes in the Commission’s Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields
  - ET Docket No. 13-84
    - Reassessment of Federal Communications Commission Radiofrequency Exposure Limits and Policies

- **OET Bulletin No. 65**

RF Safety Testing Using Magnetic Resonance Imaging (MRI)

Leeor Alon
RF Safety Testing using Magnetic Resonance Imaging (MRI)

Leeor Alon

leeoralon@yahoo.com

IEEE TC95 Meeting June 8th 2013
Outline

1. MRI Basics
2. Temperature Measurements for Antennas at MHz Frequencies
3. Temperature Measurement from a Dipole Antenna at 1.96GHz
4. Temperature Measurement from a GSM Cell Phone
5. Wireless Device 10g SAR Calculation from 3D MRI Temperature Measurements
Speaker Name: I have no conflicts of interest to disclose with regard to the subject matter of this presentation.
MRI Basics
MRI Basics

The body contains protons (water and fat)

Protons have:
- positive charge
- spin
MRI Basics

- **Tiny Magnets**
- Positively charged nuclei with an odd number of protons and/or neutrons have an **intrinsic spin**; therefore behave like a tiny magnet.
Magnetization

- At equilibrium, more spins are oriented towards the magnetic field (low energy) than away from it (high energy).

- This produces a net magnetization along the field.
RF Excitation and Reception

- RF Excitation – tips the magnetization and induces a current in a receiving coil.

Excitation

- $B_0$, $B_1$, and $M$
Chemical Shift

- In the presence of an external magnetic field, the motion of the orbital electrons can be modified to induce electronic current and generate tiny secondary magnetic fields proportional to $B_0$.

- The net magnetic field experienced by the nucleus can be expressed as

\[ B_{\text{eff}} = B_0 (1 - \sigma) \]

- where $\sigma$ is known as the shielding constant.
Chemical Shift

• Since the frequency of precession is proportional to the net field at the site of the nucleus, it is shifted by the same fractional amount.

\[ \omega_{\text{eff}} = \omega_0 (1 - \sigma) \]

• The change in frequency is known as the chemical shift, since it depends on the chemical environment of the nucleus.

• Temperature change effects the environment of the nucleus.
Proton Resonance Frequency (PRF)

- Temperature sensitivity of the proton’s frequency was first observed by Hindman* while studying intermolecular forces and hydrogen bond formation in water.

- Temperature mapping was first implemented in NMR and later adopted for MR temperature monitoring** by Ishihara.

Proton Resonance Frequency (PRF)

- To map the temperature change, an image is acquired before and after heating*. The phase of the before and after heating images are subtracted and temperature change is reconstructed.

\[ \Delta T = \frac{\phi_2 - \phi_1}{\alpha \gamma B_0 \text{TE}} \]

Outline

1. MRI Basics
2. Temperature Measurements for Antennas at MHz Frequencies
3. Temperature Measurement from a Dipole Antenna at 1.96GHz
4. Temperature Measurement from a GSM Cell Phone
5. Wireless Device 10g SAR Calculation from 3D MRI Temperature Measurements
Aim

- To evaluate the safety of RF emitting devices using MRI.

**Why MRI-based safety testing of wireless devices?**

- MRI-based safety evaluation is advantageous as:
  1. It measures temperature change, which correlated with tissue damage.
  2. It allows rapid probing of a multitude of spatial locations.
  3. Scanning resolution can be < 5x5x5mm$^3$ (0.125g).
  4. Safety tests can be conducted on complex dielectric structures rather than simple homogeneous fluid samples.
  5. Multiple frequency bands can be tested at once.
Dual Phosphorous (49.9 MHz) and Hydrogen (128 MHz) Imaging Antenna

5x5x5 mm³ resolution (0.125g)

Hydrogen Imaging Antenna (300MHz)

Heating time

<table>
<thead>
<tr>
<th>Time</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>3m20s</td>
<td>1°C</td>
</tr>
<tr>
<td>6m40s</td>
<td>2°C</td>
</tr>
<tr>
<td>10m00s</td>
<td>3°C</td>
</tr>
</tbody>
</table>

3A-B -> ~31.2% error

Brown, R. Et al. Detunable Transmit Array and Flexible Receive Array for 7T Shoulder Imaging (2013)
Multiple Transmitter Antennas, 300MHz

Safety Evaluation of Complex Antennas, 8-Transmitters (300MHz)

8-ch Parallel Transmit Triangle Coil

Cloos M. Et al. (2013), Rapid RF Safety Evaluation for Transmit-Array Coils. ISMRM.
Outline

1. MRI Basics
2. Temperature Measurements for Antennas at MHz Frequencies
3. Temperature Measurement from a Dipole Antenna at 1.96GHz
4. Temperature Measurement from a GSM Cell Phone
5. Wireless Device 10g SAR Calculation from 3D MRI Temperature Measurements
Dipole antenna setup

Dipole antenna

Power meter meas.

Directional coupler

Power amplifier

Signal generator

Two-stage Power Amplifier (max. output 4W)

Agilent E5070B Network Analyzer

Agilent 778D Directional Coupler

NYU Langone Medical Center

NYU CENTER FOR BIOMEDICAL IMAGING
Phantom

A cylindrical acrylic former with a diameter of 10.2cm and a height of 11cm was filled with gelatin-based gel, yielding:

- $\sigma = 1.5 \text{ S/m}$
- $\varepsilon_r = 35$ at 1.96Ghz – the operating frequency of the GSM mobile phone and dipole antenna.
Dipole Experiment Procedure

1. Positioned setup inside the scanner bore
2. Acquired pre-heated MRI image
3. Drove the dipole antenna with 0.65W for 6.5 minutes @ 1.96GHz
4. Acquired post-heated MRI image
5. Subtraction of phases yielded temperature change image
Dipole Experiment Procedure

1. Positioned setup inside the scanner bore
2. Acquired pre-heated MRI image
3. Drove the dipole antenna with 0.65W for 6.5 minutes @ 1.96GHz
4. Acquired post-heated MRI image
5. Subtraction of phases yielded temperature change image

Same procedure with no RF heating
MR Thermometry Sequence Error

- Voxel size = 2.7 x 2.7 x 5 mm$^3$ → \(0.05\) grams
- Total acquisition time = 31 s

\[\sigma = \pm 0.039 \, ^\circ\text{C}\]
MR Thermometry Validation

- MR Thermometry was validated against:
  - EM field simulations
  - Temperature probes
EM Simulations

The commercial Microwave Studio software suite (CST, Framingham, MA, USA) using Finite integration technique (FIT) used for simulations.

- Isotropic cell 2.7 x 2.7 x 2.7 mm$^3$
- Mesh size 84 x 83 x 83
- Voltage source at 1.96 GHz
- Separation of 5 mm between the phantom and antenna
- Net input power of 0.65W
- The EM simulation SAR fields were used as input to a temperature simulator.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Physical properties</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho$</td>
<td>Density [kg/m$^3$]</td>
<td>1272</td>
</tr>
<tr>
<td>$C$</td>
<td>Heat capacity [J/kg·°C]</td>
<td>3543</td>
</tr>
<tr>
<td>$D$</td>
<td>Heat diffusivity [mm$^2$/sec]</td>
<td>0.129</td>
</tr>
<tr>
<td>$k$</td>
<td>Thermal conductivity [W/m·°C]</td>
<td>0.457</td>
</tr>
</tbody>
</table>
Fluroptic Temperature Measurements

The experiment was monitored with fluroptical temperature probes (LumaSense, Santa Clara, CA) inserted ~4 cm into the phantom at different positions.
Results MR Thermometry vs. Simulation
## Results MR Thermometry vs. Temperature Probes

| Probe | Measured $\Delta T$ (°C) | MR thermometry (°C) | $|\text{Error}|$ (°C) |
|-------|--------------------------|---------------------|--------------------------|
| A     | 0.980                    | 1.003               | 0.023                    |
| B     | 0.820                    | 0.863               | 0.043                    |
| C     | 0.134                    | 0.179               | 0.045                    |

- The maximum temperature change was 1.62 °C.
- The measurement error < 0.15 °C from multiple experiments conducted at different times.
- The standard deviation and the mean of the measurement error were ±0.07 °C and 0.006 °C, respectively.
Outline

1. MRI Basics
2. Temperature Measurements for Antennas at MHz Frequencies
3. Temperature Measurement from a Dipole Antenna at 1.96GHz
4. Temperature Measurement from a GSM Cell Phone
5. Wireless Device 10g SAR Calculation from 3D MRI Temperature Measurements
Procedure

1. Acquired 3D pre-heated MRI image
2. Positioned the cell phone outside the scanner bore. Connected to base-station emulator to output maximum power for 15 minutes.
3. Acquired 3D post-heated MRI image
4. Subtracted phases of pre and post heating images to calculate temperature change *

*- Ishihara et al. MRM 1995;34:814-823.
Cell Phone Experiment

LG-CU920c cell phone (Seoul, Korea) was connected to base station emulator (MD8475A, Anritsu, Kanagawa, Japan)
Methods – Experiment Setup

GSM LG-CU920c cell phone (LG Electronics, Seoul, Korea)

Optical temperature probes

MR imaging knee coil
Results

The maximum temperature change generated by the phone over the RF heating duration was 0.943 °C in close proximity to the cell phone.

- Voxel size = 4 x 4 x 5 mm³ → 0.1 grams
- Total acquisition time = 21.1 s
Results

Mobile Phone Experiment
Probes Temperature Measurements and Errors in MR Thermometry

| Probe | Measured $\Delta T$ (°C) | MR thermometry (°C) | |Error| (°C) |
|-------|-------------------------|---------------------|----------------|
| A     | 0.423                   | 0.370               | 0.053          |
| B     | 0.23                    | 0.225               | 0.005          |
| C     | 0.111                   | 0.124               | 0.013          |
Outline

1. MRI Basics
2. Temperature Measurements for Antennas at MHz Frequencies
3. Temperature Measurement from a Dipole Antenna at 1.96GHz
4. Temperature Measurement from a GSM Cell Phone
5. Wireless Device 10g SAR Calculation from 3D MRI Temperature Measurements
Overview

• Deposition of RF energy can be quantified via\(^1\)
  – Local SAR
  – Temperature change

• MRI provides a tool to measure small temperature changes (<0.2 °C) as result from exposure to RF radiation\(^2\).

• Conversion of temperature-change to SAR is nontrivial
  – When heating duration is long.

Aim

• A method for 3D calculation of averaged 10g SAR via inversion of the heat equation using:
  – High-resolution 3D temperature maps
  – Measured thermal properties.

1-IEEE 1528-2003
2-Ishihara et al. (1995) MRM 34: 814-823
Theory

Heat Equation

\[ \rho C \frac{\partial T}{\partial t} = \nabla \cdot (k \nabla T) + \text{SAR}\rho \]

where \( \text{SAR} = \frac{\sigma |E|^2}{\rho} \) or \( \text{SAR} = C \frac{\Delta T}{\Delta t} \)

Linear Finite Difference Approximation

\[ T_N = (1 + L)^{N-1}T_1 + \sum_{i=0}^{N-2} (1 + L)^i f \]

where \( L = \Delta t \cdot k \cdot \nabla^2 \)

Minimization Problem for SAR

\[ \text{arg min}_f \{ \| Af - b \|_2 + \lambda \| f \|_1 \} \]

where

\[ b = T_N - (1 + L)^{N-1}T_1 \]

\[ A = \sum_{i=0}^{N-2} (1 + L)^i \]
EM Field Simulations and Experimental Setup

**EM Field Simulations for Error Analysis**

- EM Field Simulation Solves (Maxwell’s Equations)
- Extract SAR maps
- Simulation of 3D temperature change maps
- Inversion of the heat equation to get the local SAR
- Injection of realistic noise to temperature difference maps

**MR Thermometry Experiments**

- Gel Phantom
- Dipole Antenna
- Schematics of the Experiment

---

NYU Langone Medical Center

NYU Center for Biomedical Imaging
Averaged 10g SAR Results from Temperature (6 minutes heating; diffusion length=1.36cm)

EM-Field Simulation Results for Error Analysis

Error in maximum SAR: 3.2%

SAR Results from MR Thermometry Experiments
Averaged 10g SAR Results from Temperature (15 minutes heating; diffusion length=2.15cm)

ΔT + noise

10g SAR recon

10g SAR true

|Error|

Error in maximum SAR: 7.7%
Averaged 10g SAR Results from Temperature (30 minutes heating; diffusion length=3.5cm)

Error in maximum SAR: 10.5%
In Conclusion

1. MR temperature mapping can be used as a useful tool for characterizing safety of antennas at a wide-range of frequencies

2. Using our current methodologies confidence interval for the temperature measurement is \( \pm 0.08 ^\circ C \) (2\( \sigma \))
   - No extrapolation, smoothing of the temperature

3. Scanning can be conducted with resolution <5x5x5mm\(^3\) (<0.125g) within seconds

4. RF heating does not need to occur within the scanner bore, since heat diffusion is a slow process

5. The high resolution \( \Delta T \) measurements allow “inversion” heat equation to yield 10g SAR
   - Can be conducted when heating duration is long (30 minutes, where the diffusion length is \( \sim 3.05cm \)).
Collaborations /w Industry/Academia

• If these tools are of interest for your projects (or have new ideas for new projects), please let us know.

Bio-heat forward solver

Fast SAR → ΔT tool (SAR2dT)

Bio-heat reverse solver

ΔT → SAR (dT2SAR)

Glacius – MRI Temperature reconstruction tool
Thank You!

• Cem M. Deniz • Gene Cho • Daniel Sodickson