ICNIRP
INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION

# Public Consultation Template - ICNIRP Draft RF Guidelines, Appendix A, Appendix B

## Comments to be uploaded until 9.10.2018

Dear Contributor,

Thank you for participating in the public consultation of the ICNIRP draft guidelines.

Please note that it is important that ICNIRP understands exactly the points that you are making. To facilitate our task and avoid misunderstandings, please:

- be concise
- be precise
- provide supporting evidence (reference to publication, etc.) if available and helpful.

**Please provide your details below as per the online form and the provision of the privacy policy**

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| Last name, first name: MILLIGAN, Michael | Email address: | Affiliation (if relevant): Mobile & Wireless Forum |
| If you are providing these comments officially **on behalf** of an organization/company, please name this here: Mobile & Wireless Forum | | |
| ☒ I hereby agree that, for the purpose of transparency, **my identity (last and first names, affiliation and organization where relevant) will be displayed** on the ICNIRP website after the consultation phase along with my comments.<br>☐ I want my comments to be displayed anonymously. | | |

**Please complete the comments table:** Please use 1 row per comment. If required, please add extra rows to the table.

| | Document (Guidelines, App A, App B) | Line Number # | Type of comment (General/ Technical/ Editorial) | Comment. Proposed change. Context. |
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| | | | | **PRIORITY COMMENTS** |
| **1** | Guidelines | 337-344 | Technical | **Comment:** Although the pinna is mentioned at line 327 as a 'Type 1' tissue, because of the broader tissue classification adopted in line 338-339 ("head and torso"), the applicable limits seem to be those relevant to tissue ´Type 2'.<br><br>**Proposed change:** On line 340, add the pinna to the region for which 'Type 1' limits apply and change the name of the region to 'Limbs and Pinnae'.<br><br>**Context:** SAR measurements in the pinna are excluded in international compliance assessment standards because of the larger exposure limit which is typically associated to it. It is therefore relevant to avoid confusion to explicitly include the pinna in the region for which a SAR limit of 4 W/kg (general public) and 20 W/kg (occupational), applies. |
| **2** | Guidelines | 371-395 | Technical | **Comment:** The change in the averaging area from 4 $cm^2$ to 1 $cm^2$ introduces a discontinuity in the limits which is not justifiable. Line 386 specifies that "As frequency increases further, the averaging area needs to be reduced to account for the possibility of smaller beam diameters". Nevertheless, for exposure conditions for which the irradiated area is sufficiently large, an averaging area of 1 $cm^2$ will introduce unnecessary restrictions. Foster et al. (referenced at line 911) indicates that for 'very' small irradiated areas, the peak temperature elevation increases about linearly with the square root of the exposed area. If 1 $cm^2$ is used an an averaging area, incident/transmitted power density limits twice as large as those applicable for 4 $cm^2$ are justifiable.<br><br>**Proposed change:** Address the discontinuity in the applicable averaging area at 30 GHz for instance by specifying limits for both 1 $cm^2$ and 4 $cm^2$ above 30 GHz.<br><br>**Context:** for products limited by space, power supply, hardware and software complexity, we envision that most consumer products will not be able to achieve a highly concentrated beam within 1 cm^2. Therefore, the 30 GHz threshold in averaging area seems to be artificial and would impose unnecessary constraint on output power for those products |

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| **3** | Guidelines | 412 to 414 and 511 to 514 | Technical | **Comment:** Energy absorption limits are said to be valid for head, torso and limbs because "the operational health effect threshold will be met simultaneously". For $t$ = 360 s and for frequencies below 6 GHz, however, the corresponding energy density limit when averaged over time is 2 W/kg. This ensures continuity with the localized SAR limits only for the head and torso.<br><br>**Proposed change:** It is suggested to revise energy limit to ensure continuity with type 1 tissue limit on absorbed energy rate<br><br>**Context:** Without the suggested change, SAR limits fort the limbs will never apply. For an averaging time of t $\rightarrow$ 360 sec (f < 6 GHz, general public), the energy rate corresponding to the absorbed energy limit in Table 3 is 2 W/kg disregarding of the tissue type (i.e. lower than the SAR limit of 4 W/kg applicable for the limbs) |
| **4** | Guidelines | 714 to 716 | Technical | **Comment:** It is not clear why for frequencies above 6 GHz, "no reference level is provided for reactive near-field exposure condition".<br><br>**Proposed change:** "For frequencies above 6 GHz, far-field reference levels are also applicable to **reactive** and radiative near-field exposure conditions; no **separate** reference levels are provided for reactive and radiative near-field exposure conditions within this frequency range."<br><br>**Context:** Test configurations for which compliance with the localized exposure limits is to be assessed in the reactive near-field of a source cannot be ruled out at frequencies above 6 GHz. As for the lower frequencies, it should be possible to use the reference levels to ensure the availability of practical limits covering the entire frequency range . The same comment is valid for Table 5 and Table 6. |
| **5** | Appendix A | 95 | General | **Comment:** The magnitude of the Poynting vector does not provide the correct measure for incident power density. The correct definition for incident power density over an arbitrary surface $S$ can be found, for instance, in *The Feynman lectures on physics Vol. II Ch. 27: Field energy and field momentum* (available online) and it's given by the projection of the Poynting vector on the normal to $S$. Such a definition is also included in IEC TR 63170 (2018). Moreover, expression 2.12 is not consistent with expression 2.10 where the normal component of the Poynting vector is correctly considered. In addition, 2.12 is not in accordance with the energy conservation law and the Poynting theorem, possibly leading to unphysical results (i.e. the energy flux rate over 4 $cm^2$ obtained with 2.12 might be larger than the total transmitted power by the RF source). Finally, the real part of the Poynting vector is needed when the fields are expressed as complex vectors.<br><br>**Proposed change:** Replace 2.12 with $\boldsymbol{S} = \mathrm{Re}(\boldsymbol{E} \times \boldsymbol{H}^*) \cdot \hat{\boldsymbol{n}}$<br><br>**Context:** The definition of power density, as well as the other quantities used in the draft guidelines, is fundamental to ensure harmonized compliance assessments procedures. A large number of studies related to near-field EMF exposure above 6 GHz are based on the expression suggested above (e.g. He et al., RF Compliance Study of Temperature Elevation in Human Head Model |

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| | | | | Around 28 GHz for 5G User Equipment Application: Simulation Analysis, IEEE Access 2018; Colombi et al, *RF Energy Absorption by Biological Tissues in Close Proximity to Millimeter-Wave 5G Wireless Equipment, IEEE Access, 2018;* Foster et al, *Thermal response of tissue to RF exposure from canonical dipoles at frequencies for future mobile communication systems*, Electronics Letters, 2017; Pfeifer et al., *Total Field Reconstruction in the Near Field Using Pseudo-Vector E-Field Measurements*, IEEE Transactions on Electromagnetic Compatibility, 2018.)<br>If the expression currently provided in Eqn. 2.12 is considered by ICNIRP to be a more suitable quantity to express reference levels above 6 GHz compared with what suggested above, a clear motivation should be given and the name of the quantity should be modified (as it does not provide a measure for incident power density), in order to avoid future confusions and misinterpretations. |

| **OTHER COMMENTS** | | | | |
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| **6** | Guidelines | 156 | Editorial | **Comment:** Not clear why some symbols in the table are bold since they all represent scalar quantities.<br><br>**Proposed change:** Change bold symbols to normal (not just in the table but throughout the document). |
| **7** | Guidelines | 156 | General | **Comment:** Incident energy density, Hinc, as used in Table 6, is not defined in Table 1. It is also suggested to use a different symbol not be confused with the magnetic field.<br><br>**Proposed change:** Add quantity to Table 1. |
| **8** | Guidelines | 283-308 | General | **Comment:** Ziskin et al.,"Tissue Models for RF Exposure Evaluation at Frequencies above 6 GHz", *Bioelectromagnetics*, 2018 specifies "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".<br>According to the paper above, the reference levels in Table 5 between 6 GHz and 300 GHz for localized exposure are more than adequately protective for whole-body exposures. This is consistent with "Brockow et al, 2007" referenced in the draft guidelines.<br><br>**Proposed change:** Include better rationale describing why localized exposure limits above 6 GHz are not sufficient to prevent against body core temperature elevation. |

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| | | | | **Context:** Exposure limits for whole-body above 6 GHz different than the localized ones are introduced in the draft guidelines. Since this is a notable change compared with ICNIRP 1998 further explanation should be given. |
| **9** | Guidelines | 319-320 | Editorial | **Comment:** Yarmolenko et al. 2011 is missing in the list of references<br><br>**Proposed change:** Add the missing reference |
| **10** | Guidelines | 396-424 | Technical | **Comment:** Specific absorption energy and transmit energy density limits, with the corresponding reference levels, applicable for time intervals $\leq$ 6 minutes, do not appear to be derived considering that the thermal isoeffect threshold increases exponentially with decreasing exposure duration (see for instance Sienkiewicz et al., "A closer look at the thresholds of thermal damage: workshop report by an ICNIRP task group", Health Physics, 2016; Dewhirst et al, "Basic principles of thermal dosimetry and thermal thresholds for tissue damage from hyperthermia", Int. J. Hyperthermia, 2003; Yarmolenko et al.,"Thresholds for thermal damage to normal tissues: An update", Int. J. Hyperthermia, 2011; van Rhoon, "CEM 43°C thermal dose thresholds: a potential guide for magnetic resonance radiofrequency exposure levels?", Eur. Radiol., 2013)<br><br>**Proposed change:** Define thermal thresholds for short intervals according to the thermal isoeffective dose<br><br>**Context:** By applying CEM43, the resulting temperature elevation leading to an equal isoeffective dose for 1 s heating would be 4 times larger than at 6 minutes. The thermal threshold defined by ICNIRP for "rapid temperature raise" seems to be derived neglecting this effect. The corrsponding factor for other heating times can be found by applying CEM43. |
| **11** | Guidelines | 532, Table 5, Table 6 | Technical | **Comment:** Given that the averaging area changes from 4 $cm^2$ to 1 $cm^2$ at 30 GHz, a corresponding change in the exposure limit at 30 GHz is expected. It is known that the measured power density varies as a function of averaging area.<br><br>**Proposed change:** Above 30 GHz, allow two times expsoure limits for 1 $cm^2$ as compared to for 4 $cm^2$averaging area. |
| **12** | Guidelines | 681, 697 and 712 | Editorial | **Comment:** The quantity specified in the last column of table 4 "incident plane wave power density" is not defined anywhere in the Guidelines.<br><br>**Proposed change:** Replace "incident plane wave power density" with "incident power density". |

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| | | | | **Context:** In addition of being undefined, the term does not seem appropriate since incident power density is, according to the footnote in Table 4, used also in the near-field (where fields do not behave as a plane wave). |
| **13** | Guidelines | Line 693 to 695 (and line 619 with regards to the term "far-field") | Technical | **Comment:** Incident power density is a quantity well-defined everywhere including the reactive near-field (see for instance: *The Feynman lectures on physics Vol. II Ch. 27: Field energy and field momentum,* available at http://www.feynmanlectures.caltech.edu/) It is therefore not clear why the term "far-field" is used at line 619 and 693, especially since power density is said to be applicable also in the radiative near-field.<br><br>**Proposed change:** Remove the term "far-field" from lines 619 and 693.<br><br>**Context:** The usage of the term "far-field" generates ambiguity on the applicability of the reference level in the near-field. |
| **14** | Guidelines | 707 to 708 | Editorial | **Comment:** For frequencies > 400 MHz to 6 GHz the limit in Table 5 is extrapolated from Table 6. On the other hand, above 6 GHz an expression for the limit is explicitly provided although it could be deducted, in a similar fashion, from Table 6.<br><br>**Proposed change:** Adopt a consistent approach throughout Table 5. It is suggested to specify the limit value for all frequencies rather than pointing to other tables, in order to avoid confusion. |
| **15** | Guidelines | 709 | Editorial | **Comment:** The specified frequency range seems incorrect.<br><br>**Proposed Change:** Correct the typo: 6-30 GHz<br><br>**Context:** The applicable frequency range is 6 GHz to 30 GHz, not 66 GHz to 30 GHz |
| **16** | Guidelines | 727 | Technical | **Comment:** Spatially averaged power density values rather than peak values have been shown to provide a better correlation with temperature elevation. Neverthless "peak spatial Hinc" is to be used betweeen 400 MHz and 6 GHz. This also introduces a discontinuity at 6 GHz in the limits of Table 6 (Hinc is to be averaged over 4 $cm^2$ above 6 GHz).<br><br>**Proposed change:** An averaging area of 4 $cm^2$ seems more appropriate for reference levels for local exposure between 400 MHz and 6 GHz. |

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| **17** | Guidelines | 732 to 735 | Technical | **Comment:** Power density when rigorously determined based on the evaluation of the Poynting vector (i.e. on the assessment of both E-field and H-field) provides a measure of the energy flux density in the far-field as well as in the near-field. It is not clear why, rather than applying expression 2.12 of Appendix A (or more precisely the expression reported in comment no. 20), the plane wave equivalent power density should be used. In the reactive near-field compliance with both E and H field limits might be justifiable but in the radiative near-field, incident power density (without plane-wave approximation) should be used.<br><br>**Proposed change:** Delete "and radiative" at line 732. |
| **18** | Guidelines | 813 | General | **Comment:** For some products operating simultanously at different frequencies, compliance testing will be conducted according to the basic restrictions for some bands and with respect to the reference levels for some others. The possibility to assess the total exposure in this way is not considered in Section 5.4.<br><br>**Proposed change:** To avoid misunderstanding, the possibility to sum up exposure using reference levels and basic restrictions should be mentioned within section 5.4.<br><br>**Context:** For devices operating above and below 6 GHz, both incident power density and SAR are likely to be used for compliance testing. |
| **19** | Appendix A | 76 | Editorial | **Comment:** The penetration depth value at 300 GHz is not consistent with what reported in Table 3.1.<br><br>**Proposed change:** Correct value, 0.2 mm rather than 0.4 mm. |
| **20** | Appendix A | 110-114 | Technical | **Comment:** For plane-waves, incident power density is linearly related to the transmit power density through the transmission coefficient (as also noted in Eqn 2.14). Therefore, the statement in lines 110 to 114 is wrong or unclear (i.e. the incident power density of a plane wave can not underestimate the transmit power density as it is directly related to it).<br><br>**Proposed change:** Correct or delete sentence. |
| **21** | Appendix A | 339 to 341 | Technical | **Comment:** The OAHET provided for Head and Torso is 2 °C. The calculation performed at line 341 which yield to 0.2 °C is misleading (the reduction factors should be applied to the exposure limit values and not to the health effect threshold as implictly done at line 341). Moreover this sentence introduces the concept of "temperature allowable for the head and torso of the general public" which is not defined anywhere else in the document and does not seem consistent with the principles used to set the Guidelines.<br><br>**Proposed change:** Correct or delete sentence. |

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| **22** | Appendix A | 376 to 380 | Technical | **Comment:** The meaning of "focused beam" is unclear. The beam size in the far-field is related to the electrical size of the antenna and not to the frequency itself. Also, depending on the antenna separation distance, an antenna characterized by a relatively small beamwidth might lead to a relatively large exposed area. In the near-field, the coherent beam has not yet formed and the energy is typically distributed over the antenna. Eventually, therefore, a more localized exposure in the very near-field of a mmW antenna (or antenna arraya) might be due to the fact that the irradiated area could have a dimension comparable to that of the single antenna (or of one antenna element in the array) which scales down with $\lambda$.<br><br>**Proposed change:** Delete the paragraph (the concept is better explained in lines 381 to 391) |
| **23** | Appendix A | 549 to 551 | Technical | **Comment:** Even if the plane-wave approximation is typically not applicable below 30 MHz, incident power density (see comment 19) is a well-defined quantity within any distance from the source. Thus, there is no reason not to apply incident power density in the radiating near-field of a source. The rationale for providing reference levels for both E and H should be clarified in order to avoid misunderstandings in the definition and applicability of power density.<br><br>**Proposed change:** The following sentence, in place of lines 549-551, is suggested: "Below 30 GHz, reactive near field components may be dominant. Consequently , both the **E**-field and **H**-field reference levels must be met." |
| **24** | Appendix A | 702 to 704 | | **Comment:** Power density and equivalent plane wave power densitity are two different quantities (as specified also in Section 2.3 of Appendix A). The latter is a generalization of the former applicable when in the far-field. Although power density when assessed according to the plane-wave equivalent approximation might exceed the reference levels in the reactive near-field, the "rigorous" power density (as defined in comment 20) might not. Recently, measurement methodologies and equipment to assess incident power density based on the evaluation of the Poynting vector have been developed (e.g. see IEC TR 63170). This allows to accurately characterize incident power density without any plane-wave approximation.<br><br>**Proposed change:** The Guidelines should clarify if compliance can be assessed using the reference levels in the reactive near-field region (see also comments 5 and 14) when power density is evaluated without any plane-wave approximation. Colombi et al, *RF Energy Absorption by Biological Tissues in Close Proximity to Millimeter-Wave 5G Wireless Equipment, IEEE Access, 2018,* might provide suitable insights. |