Innovation, Science and Economic Development Canada
Innovation, Sciences et Développement économique Canada

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Spectrum Management and Telecommunications

Supplementary Procedure

Supplementary Procedure for Assessing Radio Frequency Exposure Compliance of Portable Devices Operating in the 60 GHz frequency band (57 GHz – 71 GHz)

Aussi disponible en français – PRS-003

Canada

Preface

This Innovation, Science and Economic Development Canada compliance procedure describes the various technical requirements and processes to be followed when demonstrating compliance to power density limits for portable devices operating in the 60 GHz frequency band (57 GHz – 71 GHz).

Issued under the authority of the Minister of Innovation, Science and Economic Development

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Martin Proulx
Director General
Engineering, Planning and Standards Branch

Contents

1. Scope

Supplementary Procedure SPR-003, Issue 1, for Radio Standards Specification RSS-102 sets out the general test methods to be followed when carrying out an RF exposure compliance assessment of portable devices operating in the 60 GHz frequency band (57 GHz – 71 GHz).

SPR-003 covers the requirements to determine the power density (basic restrictions and reference levels); however, it does not cover requirements that are based on specific absorption rate (SAR) for the frequency range from 100 kHz to 6 GHz and/or **E**-field and **H**-field to protect against nerve stimulation for the frequency range from 3 kHz to 10 MHz. A full compliance assessment of a device under test (DUT), including other transmitters within the device, must consider all exposure limits and requirements set forth in RSS-102.

2. Purpose and application

The Supplementary Procedure (SPR-003) sets out the general test methods to assess the compliance with the power density exposure limits set forth in RSS-102 for portable devices operating in the 60 GHz frequency band (57 GHz to 71 GHz) intended to be used at 20 cm or less from the user and/or bystander.

Devices operating above 6 GHz, but not within the 60 GHz frequency band, may require additional instructions on test setup, specific test procedure and/or technical requirements. As such, prior to assessing RF exposure compliance for these devices, an inquiry must be submitted to the Directorate of Regulatory Standards of Innovation, Science and Economic Development Canada (ISED), using the "General Inquiry" online form. The inquiry shall include sufficient information pertaining to the technology and operation of the device in order for ISED to determine the applicable technical and administrative requirements for the specific device.

3. Normative references

The following documents shall be consulted for the application of SPR-003. The latest version of these reference publications shall be used for showing compliance.

- Radio Standards Specification RSS-102, *Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)*.
- International Electrotechnical Commission (IEC) – TR 63170 – *Technical Report on Measurement Procedure for the Evaluation of Power Density related to Human Exposure to Radio Frequency Fields from Wireless Communication Devices Operating between 6 GHz and 100 GHz*
- International Electrotechnical Commission/Institute of Electrical and Electronics Engineers (IEC/IEEE) 62704-1 – *Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30*

MHz to 6 GHz - Part 1: General requirements for using the finite difference time-domain (FDTD) method for SAR calculations

- *Safety Code 6 — Health Canada's Radiofrequency Exposure Guidelines*
- *Technical Guide for Interpretation and Compliance Assessment of Health Canada's Radiofrequency Exposure Guidelines*

Annexes A and B within SPR-003 are normative.

ISED may consider assessment methods not covered by SPR-003 or the referenced publications. Consult the Certification and Engineering Bureau's website to determine the acceptability of any alternative measurement methods, or send an inquiry by email with the detailed information on the alternative assessment method(s).

4. Definitions and abbreviations

4.1. Definitions

Array: An antenna which contains a number of radiating elements being used to transmit (or receive) signals that are processed collectively.

Averaging Area: The area (A_{avg}) on the evaluation surface over which the assessed power density is averaged. The surface may be a square with side length $L = \sqrt{A_{avg}}$ or a circle with radius $r = \sqrt{A_{avg}/\pi}$.

Note: For the 60 GHz frequency band (57 GHz – 71 GHz), the averaging area is defined as a 1 cm^2 [square or circle].

Codebook: Description of all phase and amplitude combinations to be used by an antenna array or antenna sub-array on the device under test.

Correlated signals: Signal yielding non-zero time-domain correlation integral at some time instant.

Note: Further details on correlated signals are available in IEC Technical Report 62630

Evaluation Surface: The virtual surface or plane for the evaluation of the spatial-average power density yielding a conservative estimate of the RF exposure with respect to the limits.

Far-Field Region: The space beyond an imaginary boundary around an antenna where the angular field distribution begins to be essentially independent of the distance from the antenna. In this zone, the field has a predominant plane-wave character.

Measurement Surface: The surface over which the quantities of interest (**E** and/or **H**-field) are measured using a probe sensitive to these quantities. The peak spatial power density is not necessarily evaluated on the measurement surface. The peak spatial power density may be derived using various techniques from data gathered on the measurement surface.

Near-Field (Region): A volume of space close to an antenna or other radiating structure in which the electric and magnetic fields do not have a substantial plane-wave character, but vary considerably from point to point at the same distance from the source.

Peak spatial-average power density (psPD): The global maximum value of all spatial-average power density (S_{avg}) values defined on the evaluation surface.

Power density (local power density): The energy per unit time and unit area crossing the infinitesimal surface characterized by the norm of the Poynting vector expressed in W/m^2.

Poynting vector: The energy transfer per unit area per unit time, expressed in W/m^2

$$\mathbf{S} = \mathbf{E} \times \mathbf{H}$$

where **E** and **H** are the electric and magnetic fields as function of time, respectively.

$$\mathbf{E} = \Re(\mathbf{E}_s e^{i\omega t}), \mathbf{H} = \Re(\mathbf{H}_s e^{i\omega t})$$

For time harmonic fields,

$$\mathbf{S} = \frac{1}{2}\mathrm{Re}(\mathbf{E} \times \mathbf{H}^*)$$

Reconstruction Algorithm: mathematical techniques and procedures used to determine the distribution of power density, with known uncertainty, on the evaluation surface from the measured electric and/or magnetic fields on one or more measurement surfaces/volume as input.

Spatial-average power density: The power density averaged over a surface of area A_{avg}. It is defined at points over the full evaluation surface. In the context of this document, $\mathbf{S}_{avg}$ may be further defined as:

The spatial-averaged norm of Poynting vector on the surface A, which is an overestimation of the total energy flow per unit area and unit time averaged on a surface of area A_{avg}, where $\boldsymbol{r}$ is the center point of the area A_{avg} and T is the averaging time.

$$\mathbf{S}_{\mathrm{tot,avg}}(\mathbf{r}) = \frac{1}{\mathrm{A_{avg}}T}\iint_{\mathrm{A_{avg}}}\left\|\int_{\mathrm{T}}(\mathbf{E}(\mathbf{r}) \times \mathbf{H}(\mathbf{r}))dt\right\|\mathrm{dA}$$

For time-harmonic fields,

$$\mathbf{S}_{\mathrm{tot,avg}}(\mathbf{r}) = \frac{1}{2\mathrm{A}_{\mathrm{avg}}} \iint_{\mathrm{A}_{\mathrm{avg}}} ||\mathrm{Re}(\mathbf{E}(\mathbf{r}) \times \mathbf{H}^{*}(\mathbf{r}))||\mathrm{dA}$$

Sub-array: A subset of elements in an array that are connected together.

Note: Two (2) or more sub-arrays may share radiating elements.

4.2. Abbreviations and acronyms

This document utilizes the following abbreviations and acronyms:

A_{avg} Averaging Area

CAD Computer-Aided Design

DUT device under test

$\mathbf{E}_{peak}$ complex E vector field of the worst-case peak

FCC Federal Communications Commission

FDTD finite-difference-time-domain

$\mathbf{H}_{peak}$ complex H vector field of the worst-case peak

IEC International Electrotechnical Commission

IEEE Institute of Electrical and Electronics Engineer

ISED Innovation, Science and Economic Development Canada

MCS Modulation, Coding Scheme Index

psPD peak spatial-average power density

S_{avg} spatial-average power density

S_{tot} spatial-average power density as per def in 4.1

TER Total Exposure Ratio

TR technical report

4.3. Quantities

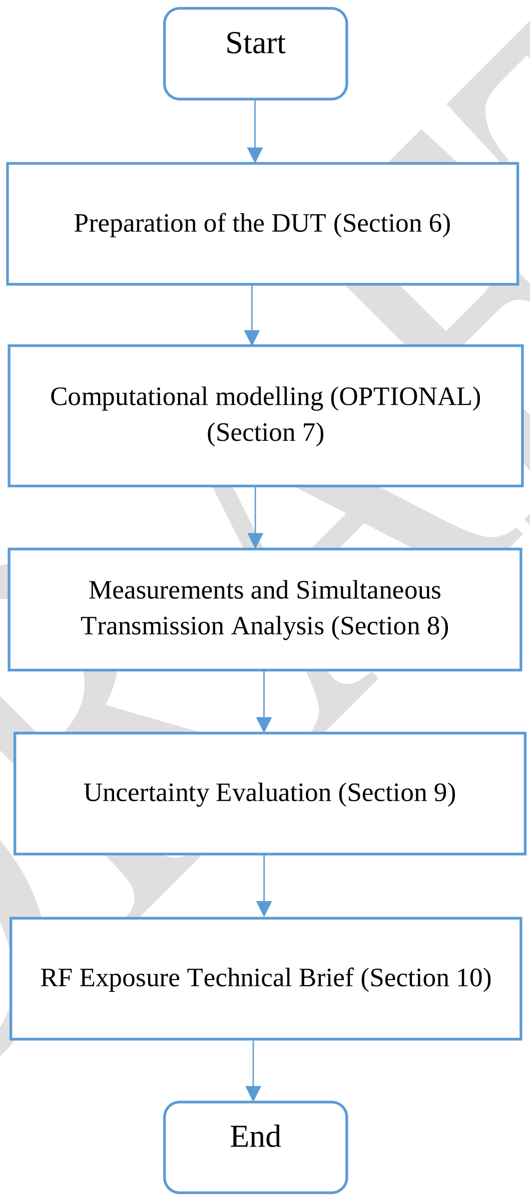
Table 1 lists the internationally accepted System of Units (SI) used throughout this document.

Table 1 — Quantities

Quantity	Symbol	Unit	Dimension
Electric Field Strength	E	volt per meter	V/m
Magnetic Field Strength	H	ampere per meter	A/m
Power Density	S	watts per square meter	W/m^2
Spatial-average Power Density	S_{avg}	watts per square meter	W/m^2

5. RF exposure compliance assessment approach

The RF exposure compliance (power density) assessment of portable devices operating in the 60 GHz frequency band (57 GHz – 71 GHz) contains many steps that have been summarized in the chart below. The assessment approach is based on Annex G of IEC TR 63170 referenced in Section 3 of this document.



When practical, all antenna configurations should be measured according to Section 8. However, when the number of possible antenna configurations is quite large, an approach based on simulations performed in the near-field, as defined above, and measurements is favoured to maximize efficiency.

Simulations can be used to determine worst-case antenna configurations followed by measurements. This approach has two main advantages: (1) it will aid to reduce the number of configurations requiring measurements; (2) the measurements will validate the simulation results.

6. Preparation of the device under test (DUT)

The preparation of the DUT is based on the principles set forth in the IEC TR 63170. As part of the preparation of the DUT, the evaluation surface, test position, test frequencies and configurations must be determined when performing the compliance assessment through computational modelling and/or measurements.

6.1. Test positions and evaluation surfaces

The test position(s) of the DUT for power density assessment shall be based on RSS-102 similar test position(s) required for SAR measurements. Other ISED recognized procedures, such as the FCC RF exposure KDB procedures also apply. A complete list of accepted procedures can be found on ISED’s Certification and Engineering Bureau website.

Two main DUT form factors are described in this document:

- The evaluation surface for a detachable laptop/tablet or wearable with a transmitter operating in the 60 GHz frequency band (57 GHz – 71 GHz) must be determined at 0 mm from the enclosure. Each side/edge of the DUT must be evaluated, unless they meet exclusion criteria accepted by ISED. For measurement, the evaluation surface is the inner shell of the virtual flat phantom, which is 2 mm from the outer surface of the phantom.

- Smartphone with a transmitter operating in the 60 GHz frequency band (57 GHz – 71 GHz) must be tested as described in RSS-102 and other relevant procedures adopted by ISED, where the main positions are:

    - the cheek and tilt positions against a virtual inner shell of the modified SAM phantom (i.e. evaluation surface);

    Note: In situation where this is not technically feasible, a planar evaluation surface tangential to the inner shell of the SAM phantom may be used. It shall be demonstrated that chosen tangential plane produces conservative psPD values. However, the differences in the planes used for evaluations (SAM phantom for SAR and evaluation surface tangential for power density) will introduce challenges combining exposure levels for simultaneous transmissions as per 8.5.3. Furthermore, at the pinna, the virtual surface of the SAM phantom is modified such that the pinna is 2 mm from the outer surface of the SAM phantom.

    - the body-worn device positions, and;

- the hand held (i.e. each side/edge) positions.

Each position of the smartphone must be evaluated unless it can be demonstrated that certain positions provide conservative values compared to other required positions.

The rationale, including a description of the evaluation surfaces and test positions, shall be provided in the RF exposure technical brief (see Section 10).

6.2. Test frequencies

The methodology and formula in Section 6.2.4 of the IEC TR 63170 may be used to determine the number of test frequencies.

6.3. Configurations to be tested

In general, the DUT shall be tested using its available operational configurations. The modulation, coding scheme index (MCS) and data rate producing the maximum output power shall be used as the test configuration to be assessed. The duty cycle used in the evaluation shall be based on the inherent property of transmission technology or of the design of the DUT.

6.4. Devices with arrays or sub-arrays

The electric and magnetic fields shall be determined on the evaluation surfaces for the test positions as per Section 6.1 for all possible combinations for each active array or sub-array. This may be done by applying the codebook to derive the power density and psPD, as defined above, from the electric and magnetic fields for each possible combination of amplitude and phase.

Alternately, for DUT which does not use codebook, the applicant shall evaluate the field for the number of elements in the array or sub-array to estimate the power density distribution on the evaluation surfaces. When all elements are fed with the same amplitude, only the possible phase combinations of each radiating element are to be evaluated. When the elements are fed with different amplitudes and phases, all the possible phase and amplitude combination shall be assessed for each radiating element. To calculate and average the power density on the evaluation surface, the assessed fields are superimposed. Field maximization techniques with known uncertainty such as: the upper-bound method shown in Section G.2 found in the Annex G of the IEC TR 63170 may be used to the determine the combinations producing the worst case psPD.

Other maximation technique may also be used provided they yield a conservative estimate of the power density. A description, including a rationale, as well as the uncertainty of the chosen maximization technique shall be documented in the RF exposure technical brief.

Each psPD found with the maximization technique shall be normalized to the radiated power (taking into account tune-up specifications and production variations). The highest psPD with different amplitudes and phases shall be reported for all test frequencies (channels). These combinations will be assessed by measurements to validate the simulations and assess power density compliance.

6.5. Devices with elements that do not operate simultaneously

The electric, magnetic fields and psPD shall be determined on the evaluation surfaces for the test positions as per Section 6.1 for each active antenna element. Section 6.5.2 of the IEC TR 63170 may be followed for this assessment. Each psPD shall be normalized to the radiated power (taking into account tune-up specifications and production variations). The psPD shall be documented in the RF exposure technical brief.

For DUT employing uncorrelated signals in different frequency bands, refer to Section 8.5.3 as additional considerations apply.

7. Computational Modelling

Computational modelling, such as finite-difference-time-domain (FDTD), may be used to determine the configurations with the highest psPD. Measurements shall then be performed for the configurations with the highest psPD (Section 8) per each test frequency. A minimum of 1 configuration per array/sub-array shall be conducted. In addition, all configurations yielding psPD within 3 dB of the RF exposure limits shall be measured up to 3 configurations per channel.

The applicant shall submit all information (see Annex A) relevant to the modelling, including an electronic copy of the simulation and modelling information necessary to reproduce the results.

The applicant is responsible for compliance with the limits specified in RSS-102, regardless of the computational model used.

Note: The applicant, when practical, may elect to conduct the entire power density assessment by measuring all the possible antenna configurations (see Section 8).

7.1. CAD Model

The DUT model used for the computations should be equivalent, and ideally identical to the actual device that will be assessed with the measurement system. The CAD file shall be made available upon ISED's request in an exchangeable format such as: *.sat, *.sab, *.step, *.stp, *.stl[1]. Note that the provisions for disclosure of information (Section 9.4) of RSP-100 apply.

Objects and layers in the CAD file shall be organized in a table where the materials and dielectrics properties (frequency dependent as per Section 6.2) are identified. Whenever possible, all conducting parts should be integrated into the CAD model with their associated frequency dependant dielectrics properties.

1 For other files format, please verify with ISED to ensure they are supported.

Truncation of the DUT model or computational domain is allowed in order to reduce computational resources. When a truncated model is used, it shall be demonstrated and documented in the RF technical brief that the truncation is of negligible impact on the RF characteristics of the DUT model

7.2. Computational Software

Software that meets the benchmark set in Annex A – Code Verification of IEC/IEEE 62704-1 may be used for the purpose of this standard. The software shall be capable of determining the power density as defined in Section 4 of this document.

Should the applicant wish to use a software that does not meet these benchmarks, ISED shall be contacted **prior** to initiating the certification process to determine if proposed software is deemed acceptable.

A summary of the software and the basic solver algorithms implementation as well as descriptions of the procedures used to validate these algorithms are required in the RF exposure technical brief (see Algorithm implementation and validation in Annex A).

7.3. Computational assessment

The DUT should be modelled in free-space and the testing configurations shall be chosen according to Section 6 and modelled appropriately.

The evaluation surface should be in the computational domain. Otherwise, the computational domain shall be chosen to ensure the reactive field of the DUT is not affected by absorbing boundary conditions.

A convergence study supporting utilized meshing parameters shall be reported for the chosen convergence criteria. The convergence and criteria/condition for simulation completion shall be provided in the RF exposure technical brief.

The psPD shall be calculated on the averaging on the evaluation surface. When the evaluation surface consist of a planar surface, the averaging area shall be a [square or circle], entirely contained in the averaging area, with the side length $\mathrm{L} = \sqrt{A_{avg}}$. When the evaluation is not planar, the averaging area shall be a circle with radius $\mathrm{r} = \sqrt{A_{avg}/\pi}$. The power passing through the surface is calculated by numerical integration of the power density over the averaging area.

7.4. Validation of the DUT CAD model

The DUT model validation found in 7.3.4 of IEC/IEEE 62704-1 may be used with the following changes.

- The measured near-field data as determined in Section 8 is used as $\nu_{\mathrm{ref}_\mathrm{n}}$

- Both the measured near-field data ν_{ref_n} (measured **E**- or **H**-field amplitude) and simulated ν_{sim_n} are to be normalized to the measured radiated power.
- The measurement uncertainty U_{ref} is the expanded uncertainty (k = 2) of the measurement system at the given frequency band from Section 9
- The numerical uncertainty U_{sim} of the near-field evaluation is determined by the following:

$$U_d(\%) = 100 \cdot \mathrm{Max}\left(\frac{\left|\nu_{\mathrm{meas}}^2(n) - \nu_{\mathrm{sim}}^2(n)\right|}{\mathrm{Max}(\nu_{\mathrm{meas}}^2(n))}\right)$$

where

$\nu_{\mathrm{meas}}^2(n)$: is the experimentally determined local square of the **E**- or **H**-field amplitude at position *n* or its accurate reference solution

ν_{sim}^2: is the numerically determined local square of the **E**- or **H**-field amplitude at position *n*

- At every point *n* at which is ν_{ref_n} or ν_{sim_n} are larger than 5% of the maximum measured or simulated value $Max(\nu_{\mathrm{sim}_n}; \nu_{\mathrm{ref}_n})$, validate whether the deviation between the measured value at point *n*, ν_{ref_n} and the simulated value ν_{sim_n} are within the combined uncertainty of U_{ref} and U_{sim} by evaluating:

$$E_n = \sqrt{\frac{\left(\nu_{\mathrm{sim}_n} - \nu_{\mathrm{ref}_n}\right)^2}{\left(\nu_{\mathrm{sim}_n} U_{\mathrm{sim}(k=2)}\right)^2 + \left(\nu_{\mathrm{ref}_n} U_{\mathrm{ref}(k=2)}\right)^2}} \leq 1$$

When En > 1, the DUT model is not within the combined standard uncertainty. The DUT model shall be revised and re-assessed until En ≤ 1.

8. Measurements

8.1. Test Environment

The test environment should be free of ambient signals. This may not be possible in all situations and, if required, background noise can be measured and removed from the final measurements. Further information on addressing ambient radio noise may be found in CISPR 16-2-3: 2016. It is expected that applicants of SPR-003 will be able to demonstrate that background noise are addressed in accordance with good engineering practice.

8.2. Measurement Equipment

The measurement system must be capable of assessing near-field psPD on the evaluation surface by performing near-field and/or far-field measurements, with known uncertainty, in the frequency range 60 GHz frequency band (57 GHz – 71 GHz).

The measurement system shall be capable of measuring the **E**-field and/or **H**-field as well as be able to compute local and spatial averaged power density, with known uncertainty, from the measured data at the evaluation surface of interest. Reconstruction algorithms may be used to generate the **H**-field from the **E**-field (or vice versa) and/or generate other field information such as the phase from the measured amplitude. The fields shall be displayed as per the units found in Table 1. The measurement system shall be validated as complete system prior to being put into operation and annually. The system shall also be validated after software and measurement components modifications.

8.3. System check

A system check shall be completed before performing power density measurements for a DUT based on Annexes A and C of the IEC TR 63170. The system check will ensure the measurement system is operating within its manufacturer's specifications with no component failures or deviation from target performance requirements.

A valid system check consists of:

- The differences (absolute values) between the measured psPD values of the calibrated antenna are within the combined uncertainty of the measurement system and the following equation:

$$\frac{\left|\mathrm{psPD_{meas}} - \mathrm{psPD_{target}}\right|}{\mathrm{psPD_{target}}} < 2 \cdot \mathrm{u_{comb}}$$

  where

$$\mathrm{u_{comb}} = \sqrt{\left(\mathrm{u^2_{cal\ ant}} + \mathrm{u^2_{rad\ power}} + \mathrm{u^2_{meas}}\right)}$$

  u_{meas}: Standard uncertainty (k = 1) for the measurement system (probe calibration, electronics, and positioning)
  $u_{rad\ power}$: Standard uncertainty (k = 1) of the radiated antenna power
  $u_{cal\ ant}$: Standard uncertainty (k = 1) of both numerical and physical modelling of the calibrated antenna

- The relative differences between the measured psPD values and target values using the same setup and radiated antenna are within the system repeatability uncertainty following equation:

$$\frac{\left|\mathrm{psPD_{meas}} - \mathrm{psPD_{sys\_check}}\right|}{\mathrm{psPD_{sys\_check}}} \cdot 100\% < \mathrm{u_{drift}}$$

  where

u_{drift} is the maximum instrumental drift (power source, probe, etc.) during a period of time, given by the system manufaturer.

The applicant shall evaluate both criteria for each system check source. As the IEC TR 63170 only provides target values at distance of 150 mm for the system check sources, for all other distances, the numerical target values or measured target values listed in the calibration certificate of each source provided by the system manufacturers may be used as target values.

Routine system checks which shall be conducted within 24 hours prior to performing power density measurements must be evaluated against both criteria. Note that the same equipment setup and system check source shall be used to evaluate both criteria. The same measurement probe and system shall be used for the DUT measurements.

The test procedure and results of the criteria above shall be provided in the RF exposure technical brief.

8.4. DUT setup for measurements

The DUT shall use its internal, integrated or connected transmitter. The antenna(s) and accessories used shall be specified in the measurement report. The RF output power and frequency (channel) shall be controlled using an internal test program or by a wireless link to a base station or network simulator.

The DUT shall be set to transmit at its highest source-based time-averaged RF output power level that is defined by the transmission mode and/or the operating requirements of the DUT, taking into account tune-up specifications and production variations. If this is not possible or practical, the test may be performed at a lower power level and then numerically scaled to the highest power level. The scaling factor shall be documented in the RF exposure technical brief.

When the normal mode of operation includes transmission in bursts without a fixed duty factor the tests shall be performed using a fixed controlled duty factor. The power density results shall then be scaled to the maximum intended duty factor for that mode and documented in the RF exposure technical brief.

When the maximum intended duty factor is not well identified or if a fixed controlled duty factor is difficult to generate, an available mode of operation shall be used. Appropriate scaling shall then be chosen and documented in the RF exposure technical brief.

The DUT shall be configured as per Section 6 to replicate the conditions yielding the worst-cases. Software are permitted to be used to this end, but it must be documented in the test report.

As cables attached to the DUT can alter the RF current distribution on the DUT surface, there should be no cables attached to the DUT, unless the cables are necessary for the functionality in the intended operational configuration. Cables that are necessary for the functionality in the intended operational configuration shall be positioned to produce conservative power density results. The cable positioning shall be documented in the RF exposure technical brief.

Where a DUT is only intended to be operated with an external power source, the manufacturer-supplied cabling should be used to connect to a suitable power source. Where a battery is the intended power source, the battery shall be fully charged before the measurements and there shall be no external power supply. A single charge of the battery may be used for a sequence of measurements as long as the drift is assessed and the power density values are corrected accordingly. Section 6.1.3.2 of IEC 62209-2 – although intended for SAR – provides further guidance.

8.5. Power density measurement

8.5.1 Evaluation Surface in the Far-Field Region

When in the far-field of a source, the **E**-field, **H**-field and power density are interrelated by simple mathematical expressions, where any one of these parameters defines the remaining two.

$$\eta = \frac{E}{H}$$

$$S_{eq} = \frac{E^2}{\eta} = H^2\eta$$

where

S_{eq}: equivalent plane-wave power density, in watts per square metre (W/m^2)
η : the characteristic impedance of free-space (377 **Ω**)

$$\mathbf{S}_{n,avg}(\mathbf{r}) = \frac{1}{2\eta A_{avg}} \iint_{A_{avg}} |\mathbf{E}|^2 dA = \frac{\eta}{2A_{avg}} \iint_{A_{avg}} |\mathbf{H}|^2 dA$$

Therefore, only the amplitude of the **E**-field or **H**-field needs to be measured on the evaluation surface to adequately derive the power density.

The minimum distance (from antenna to the evaluation surface) where the above formula is valid will vary depending on the dimension of the antenna (see Table 1 of the IEC TR 63170). For antenna where D (largest linear dimension) is below $\frac{\lambda}{3}$, the distance where S_{eq} is considered is 1.6λ. When D is between $\frac{\lambda}{3}$ and 2.5λ, the distance is 5D. Above 2.5λ, S_{eq} is considered at a distance of $\frac{2D^2}{\lambda}$.

8.5.2 Evaluation Surface in the Near-Field Region

Generally, the power density assessment will be within a short distance of the DUT and the transmitting source(s). In these situations, both the electric and magnetic fields are required to be assessed. Note that reconstruction algorithms are permitted to derive the fields from the measurement surface to the evaluation surface and to derive the magnetic field from the electric field (or vice versa)

The steps of Sections 6.4.2 of the IEC TR 63170 are to be followed to perform the power density measurements. Clarifications are only provided below when warranted.

a) No changes, a reference level of the **E**-field or **H**-field is taken at the measurement surface
b) Step b) is considered as good background information
c) The step size of planar scanners is typically less than or equal to $\frac{\lambda}{4}$ and smaller spatial resolution might be required when measurements are acquired in regions where evanescent modes are not negligible.
d) When only one field (**E**-field or **H**-field) is measured, the other field is derived using the reconstruction algorithms. When both fields are measured, each field is measured separately as per item c) above.
e) When a scan over the measurement region is time consuming, fast scanning techniques may be used to reduce the overall measurement time in order to determine the relative location of the peak PD. One approach is to conduct two (2) scans.
   i. The first – a fast scan – can be conducted by moving the field probe over the entire measurement region.
   ii. The second – a full scan – should be conducted over the region identified by i. which contains the high fields (i.e., fields that are -17 dB (2%) or higher than the peak field).
f) The S_{avg} shall be calculated on the evaluation surface and the psPD shall be evaluated;
   i. The psPD shall not be on the boundary of the evaluation surface.
   ii. A second psPD shall be evaluated by shifting the evaluation area or extending the original evaluation area such that criteria e) ii. is satisfied.

   If item i. or ii. is not met, repeat step c)

g) The same measurement as step a) is taken to evaluate power drift of the DUT. The drift may be calculated using the following formula

$$Power\ drift = \left|\frac{{Ref_1}^2 - {Ref_2}^2}{{Ref_1}^2}\right| \cdot 100\%$$

   where
   $Ref_{1,2}$: the reference levels of the **E**-field or **H**-field taken in step a) and g), respectively.

   The drift should normally be below ± 5 % and considered in the uncertainty budget. However, drifts larger than ± 5 % shall be accounted for and a rationale must be provided in the RF exposure technical brief. To ensure a conservative value for the resulting S_{avg}, drifts are not subtracted from the assessed S_{avg} evaluations.

h) The S_{avg} and psPD values on the evaluation surface shall be scaled to the maximum tune-up tolerance of the DUT and documented in the RF exposure technical brief.

8.5.3 Measurement of devices with multiple antennas or multiple transmitters

When an operational mode is capable of simultaneous multiple transmissions, operating in bands other than the 60 GHz frequency band (57 GHz – 71 GHz), this operational mode shall also be tested using procedures outlined in RSS-102 and/or SPR-002.

When operating at different frequencies, the fields generated from multiple antennas are always uncorrelated. A conservative way to assess compliance is by evaluating the total exposure ratio (TER) which shall be below unity.

$$\mathrm{TER} = \sum_{k=1}^{K} \frac{\mathrm{psPD_m}}{\mathrm{S_{m,limit}}} + \sum_{l=1}^{L} \frac{\mathrm{SAR_n}}{\mathrm{SAR_{n,limit}}}$$

where:
$\mathrm{psPD_m}$: Measured spatial-average power density
$\mathrm{S_{m,\,limit}}$: Applicable power density limits as specified in RSS-102
$\mathrm{SAR_n}$: Measured SAR value as specified in RSS-102
$\mathrm{SAR_{n,limit}}$: Applicable SAR limits as specified in RSS-102

When transmitters operating between 0.1 - 10 MHz are present, **E**-field and **H**-field based on specific absorption rate, shall also be taken into account. The TER equation becomes

$$\mathrm{TER} = \sum_{k=1}^{K} \frac{\mathrm{psPD_m}}{\mathrm{S_{m,limit}}} + \sum_{l=1}^{L} \frac{\mathrm{SAR_n}}{\mathrm{SAR_{n,limit}}} + \sum_{m=1}^{M} \left(\frac{\mathrm{E_{i\,RL-SAR}}}{\mathrm{E_{RL-SAR,limit}}}\right)^2 + \sum_{n=1}^{N} \left(\frac{\mathrm{H_{i\,RL-SAR}}}{\mathrm{H_{RL-SAR,limit}}}\right)^2$$

Similar to above, TER shall be below unity to conservatively assess compliance. ISED shall be contacted when TER exceeds unity. Additional evaluations may be considered on a case-by-case to address situations where TER exceeds unity.

In addition to the TER, the ratio of the instantaneous values of E and H based on nerve stimulation shall be below unity.

$$\sum_{p=1}^{P} \frac{E_{i\ RL-NS}}{E_{RL-NS,limit}} < 1$$

$$\sum_{p=1}^{P} \frac{H_{i\ RL-NS}}{H_{RL-NS,limit}} < 1$$

where:
$E_{i\ RL\text{-}NS}$: Measured electric field at a specific frequency as per SPR-002
$E_{RL\text{-}SAR,limit}$: SAR based reference level limit for the electric field at the measurement frequency as specified in RSS-102
$H_{i\ RL\text{-}NS}$: Measured magnetic field at a specific frequency as per SPR-002
$H_{RL\text{-}SAR,\ limit}$: SAR based reference level limit for the magnetic field at the measurement frequency as specified in RSS-102
K, L, M, N: Different transmitters assessed against S, SAR, RF field strength limits, respectively
P: Transmitter assessed against the NS limits.
Note: When both E and H RL-SAR limits are applicable for the same transmitter, only the highest contributor (E or H) needs to be taken into the TER calculation.

The TER shall be reported as per Annex C.

9. Uncertainty evaluation

The applicant shall provide the computational and measurement uncertainty budgets following the guidance in IEC/IEEE 62704-1 and IEC TR 63170, respectively. Both uncertainties may be calculated separately.

9.1. Computational

The detailed uncertainty budget table found in 7.4 of IEC/IEEE 62704-1 may be used for the numerical aspect with the following changes.

- The evaluation of the phantom dielectrics shall be replaced by an evaluation of the dielectric parameters of the DUT.
- The impact lossy conductors shall be evaluated.
  This may be done by evaluating the minimum and maximum conductivity of all conductors of the DUT using their published uncertainty specifications. The deviation shall be reported in the uncertainty budget using a rectangular probability distribution.
- The uncertainty associated with field maximization technique shall be added in the total numerical uncertainty budget.

9.2. Measurements

In addition to the uncertainty components reported in Section 7.3 of the IEC TR 63170, the following components shall also be addressed.

- The uncertainty associated with the: field probes frequency response, sensor cross coupling, field impedance dependence, readout electronics, and response time shall be taken into account. The measurement system manufacturer shall provide means to determine these uncertainty components.
- The uncertainty component introduced by the power density scaling shall be taken into account.
- The spatial-averaging uncertainty shall be taken into account.

10. RF exposure technical brief

The RF exposure technical brief shall include all information required to perform repeatable simulations, including the necessary information related to the configurations tested, the methods and instrumentation used for the assessment of the device. A comprehensive list of the required information is provided in Annex A.

If SAR and/or nerve stimulation measurements were also required to assess the full compliance of the DUT, the reporting requirements shall include the items set forth in other applicable IEC standard(s), including any additional reporting requirements identified in Annex E of RSS-102 and/or SPR-002.

Annex A – Information to Report for Power Density Assessment

Computational Modelling

(1) Computational resources
Summary of the computational resources required to perform the power density (PD) computations for the DUT model
Summary of the computational requirements with respect to modelling and computing parameters for determining the highest exposure expected for normal device operation, such as minimal computational requirements and those used in the computation
(2) Algorithm implementation and validation
Summary of the basic algorithm implementation applicable to the particular PD evaluation, including absorbing boundary conditions, source excitation methods, certain standard algorithms for handling thin metallic wires, sheets or dielectric materials, etc.
Descriptions of the procedures used to validate the basic computing algorithms and analysis of the computing accuracy based on these algorithms for the particular PD evaluation
(3) Computational parameters
Tabulated list of computational parameters such as: (1) Simulation Time (2) Dimensions of the computational domain (3) Meshing, including maximum mesh step size (4) Convergence and Criteria / Condition for Simulation Completion (5) Boundary Condition (6) DUT model separation from the absorbing boundaries (7) Any other essential parameters relating to the computational setup requirements for the PD evaluation
Description of the procedures used to handle computation efficiency and modelling accuracy for the DUT model
(4) Transmitter model implementation and validation
Description of the essential features that must be modelled correctly for the particular DUT model to be valid
Descriptions and illustrations showing the correspondence between the modelled DUT and the actual device with respect to shape, size, dimensions and near-field radiating characteristics
Verify that the DUT model is equivalent to the actual device for predicting the PD distributions
Verify the PD distribution at the high, middle and low channels, similar to those considered in PD measurements for determining the highest PD
(5) Dielectric parameters
Tabulated list of the dielectric parameters, including a description, for both the DUT and the computations
Verify that the dielectric parameters used in the PD computation are appropriate for determining the highest exposure expected for normal device operation
(6) Steady state termination procedures

Description of the criteria and procedures used to determine that sinusoidal steady state conditions have been reached throughout the computational domain for terminating the computations
Reporting the number of time steps or sinusoidal cycles executed to reach steady state
Description of the expected error margin provided by the termination procedures
(7) Evaluation Surface and test device positioning
Rationale and description of the DUT test positions used in the PD computations
Illustrations showing the evaluation surface and separation distances between the DUT model and the measurement system for the tested configurations
(8) Computing peak PD from field components
Description of the procedures used to compute the sinusoidal steady peak **E**-fields, **H**-fields, single point $\mathbf{S}_{tot}$ on the evaluation surface
Description of the expected error margin provided by the algorithms used to compute the PD at each location according to the selected field components and dielectric parameter
(9) Peak-spatially averaged PD procedures
Description of the procedures used to search for the highest peak-spatially averaged PD (psPD), including the procedures for handling inhomogeneous tissues within the one squared centimeter (1 cm^2)
Description of the expected error margin provided by the algorithms used in computing the psPD
(10) Total computational uncertainty
Description of the expected error and computational uncertainty for the DUT model, test configurations and numerical algorithms, etc.
(11) Test results for determining PD compliance
Tabulated list of the $\mathbf{E}_{peak}$, $\mathbf{H}_{peak}$ and $\mathbf{S}_{tot\text{-}peak}$ – complex **E**, **H** vector fields, and single-point power density on the evaluation surface – of the worst-case peak locations produced by the DUT for each channel
Illustrations showing the $\mathbf{E}_{peak}$, $\mathbf{H}_{peak}$ and $\mathbf{S}_{tot\text{-}peak}$ distribution of the worst-case peak locations produced by the DUT for each channel
Description of how the maximum device output rating is determined and used to normalize the PD values for each test configuration
Tabulated list of the worst-case $\mathbf{S}_{tot,avg}$ produced by the DUT
Illustrations showing the worst-case distribution $\mathbf{S}_{tot,avg}$ produced by the DUT
(12) Antenna Information
Antenna efficiency at the corresponding frequency
The far-field gain in dB at the corresponding frequency shall be provided. In addition, the far-field pattern shall be reported as per Annex B on the solid angle evaluated with step sizes of 5 degrees along phi (ϕ) and theta (θ)
(13) Feedpoint impedance or input reflection coefficient Depending on the DUT and its excitation source(s), the complex feedpoint impedance or the reflection coefficient at the corresponding frequency shall be reported. Both shall be stored in a frequency range of ±5GHz with a maximum step size of 50MHz around the operational frequency of the respective antennas. The complex feedpoint impedance and reflection coefficient shall be reported as per Annex B

Information to Report for PD Measurements

(1) Measurement system and site description
Brief description of the PD measurement system
Brief description of the test setup
Specify any other ISED recognized procedures for test configurations not covered in the IEC TR 63170 as per Section 6.1
(2) Electric and/or Magnetic field probe calibration
Description of the probe, its dimensions and sensor offset, etc.
Description of the probe measurement uncertainty
Most recent calibration date
(3) PD measurement system check
Description of system check procedure, including any non-standardized methods/calculations used to determine the system check target value(s)
Brief description of the RF radiating source used to verify the PD system performance within the operating frequency range of the test device
List of the output power, peak and psPD for the measured and expected target test configurations. Also provide the delta between the measured and expected target values along with a detailed description and supporting documentation of how the target values were derived
List of the error components contributing to the total measurement uncertainty
(4) Transmitter model implementation and validation
Description of the essential features that must be modelled correctly for the particular DUT model to be valid
Descriptions and illustrations showing the correspondence between the modelled DUT and the actual device with respect to shape, size, dimensions and near-field radiating characteristics
Verify that the DUT model is equivalent to the actual device for predicting the PD distributions
Verify the PD distribution at the high, middle and low channels, similar to those considered in PD measurements for determining the highest PD
(5) Device positioning
Description of the dielectric holder or similar mechanisms used to position the test device in the specific test configurations
Description of the positioning procedures used to evaluate the highest exposure expected under normal operating configurations
Photos, sketches and illustrations showing the device positions with respect to the measurement system, including separation distances and angles, as appropriate
Description of the antenna operating positions — extended, retracted or stowed, etc., and the configurations tested in the PD evaluation
(6) peak PD locations
Description of the coarse resolution, surface or scan procedures used to search for all possible peak PD locations
Description of the reconstruction to identify the peak PD locations at a finer spatial resolution

Description, illustration and PD distribution plots showing the peak PD locations
Identifying the peak PD locations used to evaluate the psPD
(7) Peak-spatially averaged PD procedures
Description of the fine resolution, or scan procedures used to determine the highest psPD in the averaging area
Description of the reconstruction algorithms procedures used to estimate the PD value from the measurement surface to the evaluation surface
(8) Total measurement uncertainty
Tabulated list of the error components and uncertainty values contributing to the total measurement uncertainty
Combined standard uncertainty and expanded uncertainty (for k=2) of each measurement
If the expanded measurement uncertainty is greater than the ± 2 dB (- 37 % to + 58 %), an explanation of the procedures that have been used to reduce the measurement uncertainty shall be provided
(9) Test reduction
All information, including description (with drawings and photograph, if required) and rationale, related to specific test reduction procedures
(10) Test results for determining PD compliance
If the channels tested for each configuration (left, right, cheek, tilt/ear, extended, retracted, etc.) have similar PD distributions, a plot of the highest PD for each test configuration should be sufficient; otherwise, additional plots should be included to document the differences
All of the measured S_{avg} values should be documented in a tabulated format with respect to the test configurations. The reported S_{avg} shall be scaled to the maximum tune-up tolerance of the device
The psPD shall be reported and used for determining PD compliance

Annex B – Specific Information for Power Density Computational

Far-field patterns

The complex E- field of the far field pattern shall be stored in the following format with one entry per line:

i j ϕ θ $E_{\phi r}$ $E_{\phi i}$ $E_{\theta r}$ $E_{\theta i}$

with

i, j	rectilinear grid point indices corresponding to the ϕ and θ coordinates on the solid angle
x, y, z	ϕ and θ coordinates on the solid angle in radians
$E_{\phi r}$, $E_{\phi i}$,	real and imaginary parts of complex vector field
$E_{\theta r}$, $E_{\theta i}$	components in SI units

Feedpoint impedance

frequency ReZ ImZ

with

frequency	frequency in SI units
ReZ ImZ	real and imaginary part of the feedpoint impedance in SI units

Input Impedance

frequency S11

with

frenquency	frequency in SI units
S11	Absolute value of the input reflection coefficient in dB

Annex C – Bibliography

International Electrotechnical Commission, *IEC TR 62630 Guidance for evaluating exposure from multiple electromagnetic sources*

International Electrotechnical Commission/Institute of Electrical and Electronics Engineers, *Draft IEC/IEEE 63195 Measurement procedure for the assessment of power density of human exposure to radio frequency fields from wireless devices operating in close proximity to the head and body – Frequency range of 6 GHz to 300 GHz*

International Electrotechnical Commission/Institute of Electrical and Electronics Engineers, *Draft IEC/IEEE 62704-5 Determining the power density of the electromagnetic field associated with human exposure to wireless devices operating in close proximity to the head and body using computational techniques, 6 GHz to 300 GHz*