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Supplementary Procedure

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

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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 (57-71 GHz).

Issued under the authority of the Minister of Innovation, Science and Industry

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Contents

1. Scope

Supplementary Procedure SPR-003, issue 1, for Radio Standards Specification RSS-102, *Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)*, 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 (57-71 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

This supplementary procedure 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 (57-71 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 set-up, specific test procedures 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 most recent versions 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) Technical Report (TR) 63170, *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 ISED's Certification and Engineering Bureau website to determine the acceptability of any alternative measurement methods, or send an inquiry by email with detailed information on the alternative assessment method(s).

4. Definitions and abbreviations

This section contains definitions for terms used throughout this document, as well as explanations for acronyms, abbreviations and International System (SI) units used herein.

4.1. Definitions

Array

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

Averaging area

The area on the evaluation surface over which the assessed power density is averaged (A_{avg}).

For planar evaluation surfaces, averaging is performed over a square with side length $L = \sqrt{A_{avg}}$. Otherwise, it is performed over a circle with radius $r = \sqrt{A_{avg}/\pi}$.

Note: For the 60 GHz frequency band (57-71 GHz), two frequency-dependent limits are defined. The first limit is associated with an averaging area defined as a 4 cm^2 square. The second limit, which is twice the first limit, is associated with a spatial peak that is not averaged over an area.

Codebook

A description of all phase and amplitude combinations to be used by an array or a sub-array on the device under test.

Correlated signals

Signals yielding a non-zero time-domain correlation integral at any given time.

Note: Further details on correlated signals are available in IEC TR 62630, *Guidance for evaluating exposure from multiple electromagnetic sources*.

Evaluation surface

The virtual surface or plane for the evaluation of the 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.

Note: In this space, 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.

Note: The power density is not necessarily evaluated on the measurement surface. It 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

The global maximum value of all spatial-average power density values defined on the evaluation surface.

Power density

The energy per unit area and unit time crossing the infinitesimal surface characterized by the norm of the Poynting vector, expressed in W/m2.

Poynting vector

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

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

where **E** and **H** are the electric and magnetic field vectors as functions of time, respectively.

For time-harmonic fields, $\mathbf{E} = Re(\mathbf{E_s} e^{j\omega t}), \mathbf{H} = Re(\mathbf{H_s} e^{j\omega t})$, the time-averaged Poynting vector is equal to:

$$\mathbf{S} = \frac{1}{2} Re(\mathbf{E_s} \times \mathbf{H_s}^*)$$

Reconstruction algorithm

Mathematical procedure used to determine the distribution of power density, with known uncertainty, on the evaluation surface using, as input, the measured electric and/or magnetic fields on one or more measurement surfaces or a volume.

Spatial-average power density

The power density averaged over a surface of area (A_{avg}), denoted by S_{avg} and defined at points over the full evaluation surface.

In the context of this document, S_{avg} may be further defined as the spatial-average norm of the Poynting vector on A_{avg}, which is an overestimation of the total energy flow per unit area and unit time averaged on A_{avg}. It can be expressed as:

$$S_{avg}(\mathbf{r}) = \frac{1}{A_{avg}T} \iint_{A_{avg}} \left\| \int_T (\mathbf{E}(\mathbf{r}, t) \times \mathbf{H}(\mathbf{r}, t)) dt \right\| dA$$

where:

- $\mathbf{r}$ is the centre point of A_{avg}
- T is the averaging time

For time-harmonic fields, the following equation is used:

$$S_{avg}(\mathbf{r}) = \frac{1}{2A_{avg}} \iint_{A_{avg}} \| Re(\mathbf{E}_s(\mathbf{r}) \times \mathbf{H}_s^*(\mathbf{r})) \| dA$$

Spatial peak power density

The global maximum value of the power density values defined on the evaluation surface.

Note: Unlike the peak spatial-average power density, this value is not averaged.

Sub-array

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

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

4.2. Abbreviations and acronyms

This document uses the following abbreviations and acronyms:

A_{avg} averaging area

CAD computer-aided design

dB decibel

DUT device under test

IEC International Electrotechnical Commission

IEEE Institute of Electrical and Electronics Engineers

ISED Innovation, Science and Economic Development Canada

PD power density

pPD spatial peak power density

psPD peak spatial-average power density

RF radio frequency

RL reference level

RMS root mean square

SAM specific anthropomorphic mannequin

SAR specific absorption rate

S_{avg} spatial-average power density (see definition in section 4.1 above)

TER total exposure ratio

TR technical report

4.3. Quantities

Table 1 lists the quantities used throughout this document along with their internationally accepted SI units.

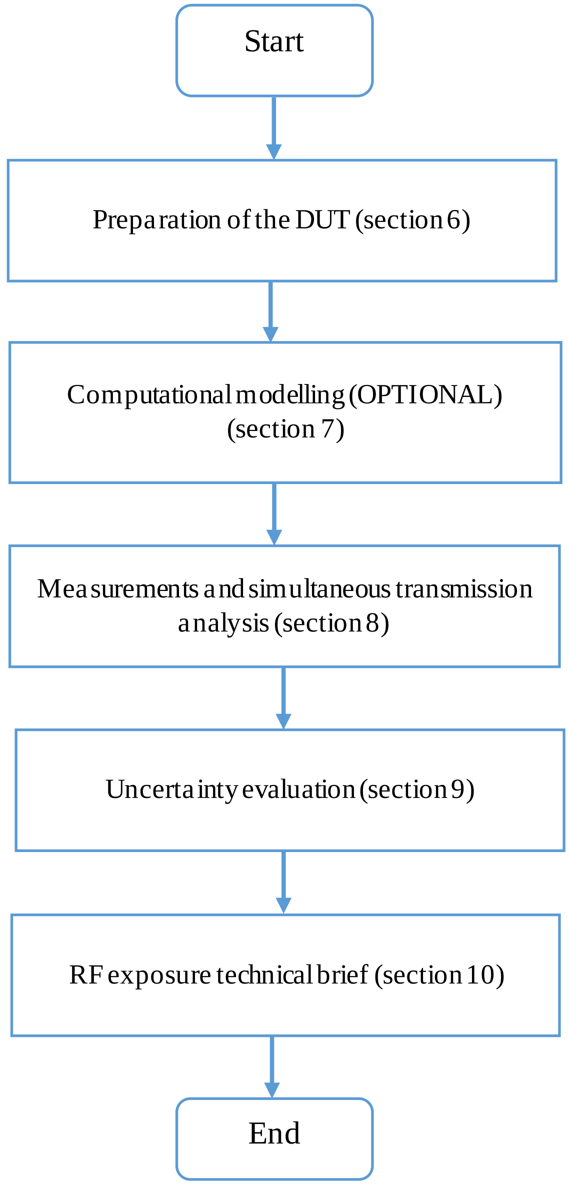
Table 1: Quantities

Quantity	Symbol	Unit (Dimension)
electric field strength	E	volt per metre (V/m)
magnetic field strength	H	ampere per metre (A/m)
power density	S	watts per square metre (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 (57-71 GHz) contains many steps that have been summarized in figure 1 below. The assessment approach is based on annex G of IEC TR 63170, referenced in section 3 of this document.

Figure 1: Summary of the approach used to assess RF exposure compliance



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 near-field simulations 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 help reduce the number of configurations requiring measurements.

2. The measurements will validate the simulation results.

6. Preparation of the device under test

The preparation of the DUT is based on the principles set forth in 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 those specified in RSS-102 for SAR measurements. Also applicable are other ISED-recognized procedures such as the Knowledge Database (KDB) procedures relating to RF exposure published by the Federal Communications Commission (FCC). 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:

1. The evaluation surface for a detachable laptop/tablet or wearable with a transmitter operating in the 60 GHz frequency band (57-71 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.

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

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

    b. the body-worn device positions

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

    In a situation where the position described in (a) 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 the chosen tangential plane produces conservative psPD and pPD 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 section 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.

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 IEC TR 63170 must 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 and Coding Scheme (MCS) index 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 properties of the transmission technology or the design of the DUT.

6.4. Devices with arrays or sub-arrays

Assessments shall be performed for each active array or sub-array. The assessment shall consist in determining the electric and magnetic field strengths on the evaluation surfaces corresponding to each test position, identified as per section 6.1 of this document, for each applicable combination of amplitude and phase excitations. These field strength values are used to derive the corresponding pPD and psPD values.

If a codebook is employed, only the amplitude and phase combinations it contains need to be assessed. Otherwise, the applicant shall evaluate the fields for all the elements in the array or sub-array to estimate the power density distribution on each evaluation surface. For each element, the fields shall be evaluated for all possible amplitude and phase excitations. When all elements are fed with the same amplitude, only the possible phase excitations are to be evaluated. 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 of annex G of IEC TR 63170, may be used to determine the combinations producing the worst-case psPD and pPD.

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

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

6.5. Devices with elements that do not operate simultaneously

Assessments shall be performed for each active antenna element. The assessment shall consist in determining the electric and magnetic field strengths on the evaluation surfaces corresponding to each test position, identified as per section 6.1 of this document. The guidance provided in section 6.5.2 of IEC TR 63170 may be followed. Each psPD and pPD shall be normalized to the radiated power (taking into account tune-up specifications and production variations). The psPD and pPD shall be documented in the RF exposure technical brief.

If the DUT employs uncorrelated signals in different frequency bands, refer to section 8.5.3 of this document because additional considerations apply.

7. Computational modelling

Computational techniques, such as finite-difference time-domain (FDTD), may be used to determine the configurations with the highest psPD and pPD for each test frequency. Measurements shall then be performed for these configurations as per section 8. At a minimum, the configuration yielding the highest exposure shall be measured for each array/sub-array. When the simulated psPD and pPD results are within 3 dB of the RF exposure limits, the three configurations yielding the highest exposure levels shall be measured for each array/sub-array.

For each configuration to be measured, the following computational results shall be provided in the RF exposure technical brief:

- plots of the power density on the evaluation surface before and after spatial averaging is applied
- a tabulated list of the pPD and psPD values, along with their locations on the evaluation surface
- a tabulated list of the RMS E- and H-field levels at the pPD locations on the evaluation surface

The applicant shall submit all information relevant to the modelling (see section A1), 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. Computer-aided design (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 (for other file formats, please verify with ISED to ensure they are supported). Note that the provisions for disclosure of information as described in section 12.4 of RSP-100, *Certification of Radio Apparatus and Broadcasting Equipment*, apply.

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

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 exposure technical brief that the truncation has a negligible impact on the RF characteristics of the DUT model.

7.2. Computational software

Software that meets the code verification requirements of IEC/IEEE 62704-1 may be used for the purpose of this supplementary procedure. The software shall be capable of determining the power density as defined in section 4 of this document.

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

A summary of the software and the implementation of the electromagnetic solver as well as associated validation procedures 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 components of the DUT are 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 power density shall be calculated on the evaluation surface. The spatial peak shall be identified and reported in the RF exposure technical brief. Additionally, the psPD shall be calculated on the evaluation surface. When the evaluation surface is planar, the averaging area shall be a square, entirely contained in the evaluation surface, with the side length $L = \sqrt{A_{avg}}$. When the evaluation surface is not planar, the averaging area shall be a circle with radius $r = \sqrt{A_{avg}/\pi}$. 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 section 7.3 of IEC/IEEE 62704-1 may be used with the following changes:

- The simulated power density values at each position n on the evaluation surface shall be normalized to the radiated power. These values are denoted as $\nu_{\text{sim}}(n)$.
- The measured power density values at each position n on the evaluation surface, obtained in accordance with section 8 of this document, shall be normalized to the radiated power. These values are denoted as $\nu_{\text{meas}}(n)$.
- The numerical uncertainty U_{PD} shall be used instead of U_{SAR} for near-field evaluations and is determined by the following:

$$U_{PD}(\%) = 100 \cdot Max\left(\frac{|\nu_{\text{meas}}(n) - \nu_{\text{sim}}(n)|}{Max(\nu_{\text{meas}}(n))}\right)$$

- The measurement uncertainty U_{meas} is the expanded uncertainty (k = 2) of the measurement system at the given frequency band obtained in accordance with section 9 of this document.
- At each position n at which $\nu_{meas}(n)\ or\ \nu_{sim}(n)$ is larger than 5% of the maximum measured or simulated value $Max(\nu_{sim}(n); \nu_{meas}(n))$, validate whether the deviation between the measured value at position n, $\nu_{meas}(n)$ and the simulated value $\nu_{sim}(n)$ are within the combined uncertainty of U_{meas} and U_{sim} by evaluating:

$$\xi_n = \sqrt{\frac{(\nu_{sim}(n) - \nu_{meas}(n))^2}{\left(\nu_{sim}(n)U_{sim(k=2)}\right)^2 + \left(\nu_{meas}(n)U_{meas(k=2)}\right)^2}} \leq 1$$

When $\xi_n > 1$, the DUT model is not within the combined standard uncertainty. The DUT model shall be revised and reassessed until $\xi_n \leq 1$.

8. Measurements

This section contains detailed information on 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 the International Special Committee on Radio Interference (CISPR) standard 16-2-3: 2016. It is expected that applicants of SPR-003 will be able to demonstrate that background noise is addressed in accordance with good engineering practice.

8.2. Measurement equipment

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

The measurement system shall be capable of measuring the E-field and/or H-field as well as computing the power density and performing spatial averaging, 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 results shall be given in the units found in table 1 (see section 4.3).

8.3. System validation and system check

This section should be used in conjunction with annexes A, B and C of IEC TR 63170. The modifications outlined below shall be performed to satisfy the requirements of SPR-003.

8.3.1. System validation

The measurement system shall be calibrated by the system manufacturer. A system validation based on annexes A and C of IEC TR 63170 shall be performed to ensure that the system provides results within the specified uncertainty. The validation shall be done before the system is put in operation, and annually thereafter. The system shall also be validated if any modifications to software or hardware components are made that may affect the power density assessment, e.g. reconstruction algorithms, probe(s), and electronic components.

8.3.2. System checks

System checks are intended to be reliable and fast. They ensure the measurement system is operating within the manufacturer's specifications with no failures or deviation from target performance requirements. System checks shall be conducted by the user of the measurement system.

Upon the installation of a system, a reference system check using calibrated sources with traceable target values is required in order to:

- verify that the performance of the measurement system has not been altered during shipment or installation
- establish acceptable criteria for reference (absolute) system checks for the test laboratory to use in their evaluation of routine (relative) system checks

The sources shown in annex B of IEC TR 63170 shall be used for the reference system check. Because IEC TR 63170 provides only target values at a distance of 150 mm for the system check sources, the numerical target values or measured target values listed in the calibration/verification certificate of each source may be used as target values for all other distances.

In the reference system check, the differences between all the measured psPD values and the target values $(\Delta psPD_{target})$ of the calibrated source are checked to ensure they are within the combined uncertainty of the measurement system, using the following equation:

$$\Delta psPD_{target} = \left| 10 \cdot log\left(\frac{psPD_{meas}}{psPD_{target}}\right)\right|$$

where:

- $psPD_{meas}$ is the measured psPD, normalized to 0 dBm radiated power
- $psPD_{target}$ is the target psPD value, derived from numerical modelling, normalized to 0 dBm radiated power

The value of $\Delta psPD_{target}$ shall be less than twice the combined measurement uncertainty, denoted by $u_{combined}$, which is expressed as:

$$u_{combined} = \sqrt{(u_{cal\_ant}^2 + u_{rad\_power}^2 + u_{meas}^2)}$$

where:

- u_{meas} is the standard uncertainty (k = 1) for the measurement system (probe calibration, electronics, and positioning)
- u_{rad_power} is the standard uncertainty (k = 1) of the radiated antenna power
- u_{cal_ant} is the standard uncertainty (k = 1) of both numerical and physical modelling of the calibrated antenna

In addition, the value of $2 \cdot u_{combined}$ shall not exceed 2 dB.

Subsequent routine system checks are introduced to verify the repeatability between power density measurements when the compliance assessment is initiated. A routine system check is performed to detect errors resulting from measurement drift, component failures and issues with the set-up.

Unlike the initial reference system check, the source for the routine system check is not required to be calibrated. However, it shall be a stable source. The result of the routine system check shall be compared to that of the reference system check.

The user of the measurement system may choose a calibrated source for the routine system check, following the guidance provided above, to determine if the reference system check results are valid.

In the routine system check, the differences between all the measured psPD values and the reference values $(\Delta psPD_{reference})$, using the same equipment set-up and source, are checked to ensure they are within the combined relative uncertainty of the measurement system, using the following equation:

$$\Delta psPD_{reference} = \left| 10 \cdot log\left(\frac{psPD_{meas}}{psPD_{reference}}\right) \right|$$

where:

- $psPD_{meas}$ is the measured psPD, normalized to 0 dBm radiated power
- $psPD_{reference}$ is the target psPD value, derived from the reference source, normalized to 0 dBm radiated power

The value of $\Delta psPD_{reference}$ shall be less than twice the combined measurement uncertainty denoted by $u_{relative}$, which is expressed as:

$$u_{relative} = \sqrt{\left(u^2_{power\_relative} + u^2_{meas\_relative}\right)}$$

where:

- $u_{meas\_relative}$ is the standard uncertainty (k = 1) for the relative measurement system (probe calibration, electronics, and positioning)
- $u_{power\_relative}$ is the standard uncertainty (k = 1) of the radiated antenna power

In addition, the value of $2 \cdot u_{relative}$ shall not exceed the lesser of:

- 0.42 dB
- 2 dB - $\Delta psPD_{target}$ (obtained from the reference system check)

Routine system checks shall be performed no more than 24 hours before power density measurements are performed. For each routine system check, the same equipment set-up and source shall be used. The same measurement probe and system shall be used for the DUT measurements.

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

8.4. DUT set-up for measurements

The DUT shall use its internal, integrated or connected transmitter. The antenna(s) and accessories used shall be specified in the RF exposure technical brief. 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 the highest source-based time-averaged RF output power defined by the transmission mode and/or the operating requirements of the DUT, taking into account tune-up tolerances and production variations. If this is not feasible, 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 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-case power density results. Software provided by the manufacturer may be used for this purpose, as long as it is clearly documented in the RF exposure technical brief.

Cables should not be attached to the DUT during testing because they can alter the associated RF current distribution. If attached cables are necessary for the intended operational configuration, they shall be positioned to produce conservative power density results, and the 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

This section contains detailed information on power density measurement.

8.5.1. Evaluation surface in the far-field region

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

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. Thus the spatial average power density can be expressed as:

$$S_{avg}(r) = \frac{1}{2\eta A_{avg}} \iint_{A_{avg}} |E|^2 dA = \frac{\eta}{2A_{avg}} \iint_{A_{avg}} |H|^2 dA$$

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

8.5.2. Evaluation surface in the near-field region

Generally, the power density assessment will be close to the DUT and the transmitting source(s). In these situations, both the electric and magnetic fields shall be assessed. Reconstruction algorithms may be used 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 in section 6.4.2 of IEC TR 63170 shall be followed to perform the power density measurements. Clarifications related to these steps are provided below when warranted:

a. No changes. A reference level of the E-field or H-field is taken at the measurement surface.
b. No changes. Step (b) also contains good background information.
c. The step size of planar scanners is typically less than or equal to $\lambda/4$ 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.

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 psPD. One approach is to conduct two 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) above, which contains the high fields (i.e. fields that are within 17 dB of 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. Should the pdPD be located on the boundary, a second scan shall be conducted by shifting the evaluation surface or extending the original evaluation surface.

   If the criteria in (i) or (ii) are not met, the measurement region shall be expanded and the process repeated from step (b).

g. The same measurement as step (a) is taken to evaluate the 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:

   $Ref_{1,2}$ are the reference values of the E-field or H-field taken in steps (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 the rationale shall 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 pPD, 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 multiple simultaneous transmissions, operating in bands other than the 60 GHz frequency band (57-71 GHz), this operational mode shall also be tested using procedures outlined in RSS-102 and/or SPR-002, *Supplementary Procedure for Assessing Compliance with RSS-102 Nerve Stimulation Exposure Limits*.

When operating at different frequencies, the fields generated from multiple antennas are always uncorrelated. A conservative way to assess compliance with the SAR-based limits is to evaluate the corresponding total exposure ratio (TER), which can be expressed as:

$$TER_{SAR} = \sum_{n=1}^{N} ER_{SAR,n} + \sum_{m=1}^{M} ER_{PD,m} + \sum_{k=1}^{K} ER_{EH-SAR,k}$$

where:

- TER_{SAR} is the SAR-based TER
- N is the total number of transmitters for which a SAR assessment has been performed
- $ER_{SAR,n}$ is the exposure ratio contribution from the n-th transmitter for which a SAR assessment has been performed
- M is the total number of transmitters for which a PD assessment has been performed;
- $ER_{PD,m}$ is the exposure ratio contribution from the m-th transmitter for which a PD assessment has been performed
- K is the total number of transmitters for which an assessment against the SAR-based reference levels for the incident E- and H-fields has been performed
- $ER_{EH-SAR,k}$ is the exposure ratio contribution from the k-th transmitter for which an assessment against the SAR-based reference levels for the E- and H-fields has been performed

The exposure ratio resulting from a SAR assessment can be expressed as:

$$ER_{SAR,n} = \frac{SAR_n}{SAR_{BR,n}}$$

where:

- SAR_n is the SAR value for the n-th transmitter
- $SAR_{BR,n}$ is the basic restriction for SAR that is applicable to the n-th transmitter

For transmitters operating above 6 GHz, it is necessary to perform an assessment against the PD reference levels. The exposure ratio for the m-th transmitter is given by:

$$ER_{PD,m} = \begin{cases} \dfrac{psPD_m}{psPD_{RL,m}}, & f_m \leq 30\ GHz \\ max\left[\dfrac{psPD_m}{psPD_{RL,m}}, \dfrac{pPD_m}{pPD_{RL,m}}\right], & f_m > 30\ GHz \end{cases}$$

where:

- $psPD_m$ is the psPD value for the m-th transmitter
- $psPD_{RL,m}$ is the applicable psPD reference level for the m-th transmitter
- f_m is the operating frequency of the m-th transmitter
- pPD_m is the pPD value for the m-th transmitter
- $pPD_{RL,m}$ is the applicable pPD reference level for the m-th transmitter

When taking into account contributions from transmitters operating below 10 MHz, it is necessary to perform an assessment against the SAR-based reference levels for the incident E- and/or H-fields. The corresponding exposure ratio is given as:

$$ER_{EH-SAR,k} = \begin{cases} \left(\frac{H_{SAR,k}}{H_{RL-SAR,k}}\right)^2, & 100\ kHz \leq f_k < f_{env} \\ \max\left[\left(\frac{E_{SAR,k}}{E_{RL-SAR,k}}\right)^2, \left(\frac{H_{SAR,k}}{H_{RL-SAR,k}}\right)^2\right], & f_{env} \leq f_k < 10\ MHz \end{cases}$$

where:

- $H_{SAR,k}$ is the root-mean-square (RMS) incident H-field from the k-th transmitter, time-averaged in accordance with a SAR-based assessment
- $H_{RL-SAR,k}$ is the SAR-based reference level for the incident H-field which is applicable to the k-th transmitter
- f_k is the operating frequency of the k-th transmitter
- $E_{SAR,k}$ is the RMS incident E-field from the k-th transmitter, time-averaged in accordance with a SAR-based assessment
- $E_{RL-SAR,k}$ is the SAR-based reference level for the incident E-field that is applicable to the k-th transmitter
- f_{env} is 1.10 MHz when considering the limits for uncontrolled environments and 1.29 MHz when considering the limits for controlled environments, as per Health Canada's Safety Code 6

Compliance with the SAR-based RF exposure limits is achieved if $TER_{SAR} \leq 1$. Situations where the TER exceeds unity shall be reported to ISED. Alternative methods considering point-by-point evaluations may be considered on a case-by-case basis. The TER shall be documented in the RF exposure technical brief.

It is also important to demonstrate compliance with the exposure limits to prevent nerve stimulation. However, the assessment is performed separately and the resulting exposure ratios are not added to the TER_{SAR}.

9. Uncertainty evaluation

This section contains detailed information on uncertainty budgets.

9.1. Computational uncertainty

The applicant shall provide the computational uncertainty budget. The detailed table on uncertainty budgets found in section 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 of 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 the field maximization technique shall be included in the total numerical uncertainty budget.

9.2. Measurements

The applicant shall provide the measurement uncertainty budget. In addition to the uncertainty components reported in section 7.3 of IEC TR 63170, the following components shall be taken into account:

- the uncertainty associated with the frequency response, sensor cross-coupling, field impedance dependence, readout electronics, and response time of the field probes (and the measurement system manufacturer shall provide the means to determine these uncertainty components)
- the uncertainty introduced when performing power density scaling
- the spatial-average uncertainty
- the spatial peak uncertainty

10. RF exposure technical brief

The RF exposure technical brief shall include all information required to reproduce the simulation and measurement results, including information related to the test configurations, methods and instrumentation. 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 ISED 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

This annex contains a comprehensive list of the information that must be included in the radio frequency (RF) exposure technical brief to demonstrate compliance with power density (PD) limits for portable devices operating in the 60 GHz frequency band (57-71 GHz).

Sections A1 and A2 provide details on the information to report for computational modelling and measurements, respectively.

A1. Information to report for computational modelling
(1) Computational resources
Summary of the computational resources used to perform the PD computations for the device under test (DUT) model
Summary of the minimum computational requirements for reproducing the assessment results
(2) Algorithm implementation and validation
Summary of the software and the implementation of the electromagnetic solver applicable to the particular PD evaluation, including absorbing boundary conditions, source excitation methods, methods 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/conditions for simulation completion 5. boundary conditions 6. DUT model separation from the absorbing boundaries 7. any other essential parameters relating to the computational set-up 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
Verification of the DUT model to ensure its equivalency with the actual device in predicting the PD distributions
Verification of 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 computational domain

Verification of the dielectric parameters used in the PD computation to ensure they 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 to terminate the computations
Report of the number of time steps or sinusoidal cycles executed to reach a 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 spatial peak power density from field components
Description of the procedures used to compute the sinusoidal steady-state peak E-fields, H-fields, single point S_{avg} on the evaluation surface
Description of the procedures used to search for the highest spatial peak power density (pPD)
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 parameters
Description of the expected error margin provided by the algorithms used in computing the pPD
(9) Peak spatial-average power density procedures
Description of the procedures used to search for the highest peak spatial-average power density (psPD), including the procedures for handling inhomogeneous tissues within four squared centimetres (4 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) Computational results
Description of how the maximum device output rating is determined and used to normalize the PD values for each test configuration
Plots of the PD on the evaluation surface, both before and after spatial averaging is applied, for each test configuration to be measured
Tabulated list of the pPD and psPD values, along with their locations on the evaluation surface(s)
Tabulated list of the RMS E- and H-field levels at each pPD location
(12) Antenna information
Antenna efficiency at the corresponding frequency
Far-field gain (in dB) at the corresponding frequency
Far-field pattern (as per annex B) on the solid angle evaluated with step sizes of five degrees along phi (ϕ) and theta (θ)
(13) Feedpoint impedance or input reflection coefficient
Complex feedpoint impedance or the reflection coefficient at the corresponding frequency, as per annex B (with a span of ±5 GHz and a maximum step size of 50 MHz)

A2. Information to report for measurements
(1) Measurement system and site description
Brief description of the PD measurement system
Brief description of the test set-up
Specifications regarding any other ISED-recognized procedures for test configurations not covered in 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
Notes regarding the radiated power, pPD and psPD for the measured and expected target test configurations
Notes regarding the absolute error in dB between the measured and expected target values along with a detailed description and supporting documentation showing how the target values were derived
List of the error components contributing to the total measurement uncertainty
(4) 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
(5) Location of pPD
Description of the coarse resolution, surface or scan procedures used to search for all possible pPD locations
Description of the reconstruction algorithms and procedures used to identify the pPD locations at a finer spatial resolution
Description, illustration and PD distribution plots showing the pPD locations
Identification of the pPD locations used to evaluate the psPD
(6) Peak spatial-average power density 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
(7) 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
(8) Test reduction
All information, including a description (with drawings and photographs, if required) and a rationale related to specific test reduction procedures
(9) Test results for determining power density compliance
One plot of the highest PD for each test configuration (left, right, cheek, tilt/ear, extended, retracted, etc.) when the channels tested for each configuration have similar PD distributions or additional plots showing distribution differences
Measured S_{avg} values in a tabulated format for each test configuration (with the reported S_{avg} scaled to the maximum tune-up tolerance of the device)
Notes regarding psPD and pPD used to determine PD compliance

Annex B: Specific information related to power density computations

This annex contains specific information related to power density computations.

B.1. Far-field patterns

The complex E-field of the far-field pattern shall be provided in a comma- or space-separated format, with one entry per line:

$i, j, \phi, \theta, E_{\phi r}, E_{\phi i}, E_{\theta r}, E_{\theta i}$

where:

- i and j are rectilinear grid point indices corresponding to the ϕ and θ coordinates on the solid angle
- ϕ and θ are the ϕ and θ coordinates on the solid angle in radians
- $E_{\phi r}$ and $E_{\phi i}$ are the real and imaginary parts of the ϕ component of the E-field
- $E_{\theta r}$ and $E_{\theta i}$ are the real and imaginary parts of the θ component of the E-field

B.2. Feedpoint impedance

The feedpoint impedance shall be provided in a comma- or space-separated format, with one entry per line:

f, Z_r, Z_i

where:

- f is the frequency in GHz
- Z_r and Z_i are the real and imaginary parts of the feedpoint impedance in Ω

B.3. Reflection coefficient

The reflection coefficient shall be provided in a comma- or space-separated format, with one entry per line:

$f, |S_{11}|$

where:

- f is the frequency in GHz
- $|S11|$ is the absolute value of the input reflection coefficient in dB

Annex C: Bibliography

The following draft documents were consulted in the preparation of this supplementary procedure:

- International Electrotechnical Commission/Institute of Electrical and Electronics Engineers (IEC/IEEE) 63195-1, *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* (draft)
- International Electrotechnical Commission/Institute of Electrical and Electronics Engineers (IEC/IEEE) 63195-2, *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* (draft)