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RSS-102.IPD.SIM
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Spectrum Management and Telecommunications

Radio Standards Specification

# Simulation Procedure for Assessing Incident Power Density (IPD) Compliance in Accordance with RSS-102

Aussi disponible en français – CNR-102.DPI.SIM

# Preface

Radio Standards Specification RSS-102.IPD.SIM, *Simulation Procedure for Assessing Incident Power Density (IPD) Compliance in Accordance with RSS-102,* issue 1, replaces Supplementary Procedure SPR-003, *Supplementary Procedure for Assessing Radio Frequency Exposure Compliance of Portable Devices Operating in the 60 GHz Frequency Band (57-71 GHz),* issue 1, dated March 2021.

This document is associated with the modernization of RSS-102, *Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)*. IPD-related simulation procedures are consolidated into this document to simplify the identification of procedures related to IPD testing based on simulations.

The content of this document is nearly identical to SPR-003, issue 1, with the following exceptions:

1. requirements for measurements are now located in RSS-102.IPD.MEAS, *Measurement Procedure for Assessing Incident Power Density (IPD) Compliance in Accordance with RSS-102*
2. various editorial changes

Inquiries may be submitted by one of the following methods:

1. Online using the General Inquiry form (in the form, select the Directorate of Regulatory Standards radio button and specify "RSS-102" in the General Inquiry field)

2. By mail to the following address:

   Innovation, Science and Economic Development Canada
   Engineering, Planning and Standards Branch
   Attention: Regulatory Standards Directorate
   235 Queen St
   Ottawa ON  K1A 0H5
   Canada

3. By email to consultationradiostandards-consultationnormesradio@ised-isde.gc.ca

Comments and suggestions for improving this standard may be submitted online using the Standard Change Request form, or by mail or email to the above addresses.

All Innovation, Science and Economic Development Canada publications related to spectrum management and telecommunications are available on the Spectrum management and telecommunications website.

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

Martin Proulx
Director General
Engineering, Planning and Standards Branch

## Contents

## 1. Scope

This Radio Standards Specification (RSS) sets out the general simulation methods to be followed when carrying out a radio frequency (RF) exposure compliance assessment of portable devices operating in the 60 GHz frequency band (57-71 GHz).

### 1.1. Purpose and application

This standard shall be used with other applicable RSSs. This document outlines the simulation-based assessments of devices subject to incident power density (IPD) compliance limits. This document is intended to replace the IPD provisions contained in Supplementary Procedure SPR-003, *Supplementary Procedure for Assessing Radio Frequency Exposure Compliance of Portable Devices Operating in the 60 GHz Frequency Band (57-71 GHz)*, issue 1.

The content of this issue of RSS-102.IPD.SIM is limited to the assessment of portable devices operating in the 60 GHz frequency band (57-71 GHz) with a combined simulation and measurement approach. Future issues of this document will:

- expand the requirements to cover the assessment of portable devices operating from 6 GHz to 300 GHz
- allow compliance assessment to be completed by employing either measurements or simulations only

### 1.2. Transition period

RSS-102.IPD.SIM will be in force as of the date of its publication on Innovation, Science and Economic Development Canada's (ISED) website. However, a transition period of 12 months from the publication date will be provided, within which compliance with the IPD provisions in SPR-003, issue 1, RSS-102.IPD.SIM, issue 1, or RSS-102.IPD.MEAS, *Measurement Procedure for Assessing Incident Power Density (IPD) Compliance in Accordance with RSS-102*, issue 1, will be accepted.

A copy of SPR-003, issue 1, is available upon request by emailing consultationradiostandards-consultationnormesradio@ised-isde.gc.ca.

## 2. Normative references

The documents that are listed on the Radio Frequency (RF) Exposure Normative References and Acceptable Knowledge Database web page shall be consulted as applicable and available, in conjunction with this RSS.

ISED may consider assessment methods not covered by RSS-102.IPD.SIM 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 emailing consultationradiostandards-consultationnormesradio@ised-isde.gc.ca with detailed information on the alternative assessment method(s).

## 3. Definitions, abbreviations/acronyms and quantities

This section provides definitions and abbreviations/acronyms for terms used in this document, as well as the symbols/units used for quantities.

### 3.1. Definitions

In addition to the definitions in RSS-102, the following terms and definitions apply to this standard:

**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 $L = \sqrt{\boldsymbol{A_{avg}}}$. Otherwise, it is performed over a circle with radius $r = \sqrt{\boldsymbol{A_{avg}/\pi}}$.

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.

**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.

**Near-field (region):** The 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/m$^2$.

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

$$\boldsymbol{S} = \boldsymbol{E} \times \boldsymbol{H} \tag{1}$$

where $\boldsymbol{E}$ and $\boldsymbol{H}$ are the electric and magnetic field vectors as functions of time, respectively.

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

$$\boldsymbol{S} = \frac{1}{2} Re(\boldsymbol{E}_s \times \boldsymbol{H}_s^*) \tag{2}$$

**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:

$$S_{avg}(\boldsymbol{r}) = \frac{1}{A_{avg}T} \iint_{A_{avg}} \left\| \int_T \left( \boldsymbol{E}(\boldsymbol{r}, t) \times \boldsymbol{H}(\boldsymbol{r}, t) \right) dt \right\| dA \tag{3}$$

where:

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

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

$$S_{avg}(\boldsymbol{r}) = \frac{1}{2A_{avg}} \iint_{A_{avg}} \left\| Re\left( \boldsymbol{E}_s(\boldsymbol{r}) \times \boldsymbol{H}_s^*(\boldsymbol{r}) \right) \right\| dA \tag{4}$$

**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.

### 3.2. Abbreviations/acronyms

This document uses the following abbreviations and acronyms:

$A_{avg}$ averaging area

CAD computer-aided design

dB decibel

EUT equipment 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
RMS root mean square

$S_{avg}$ spatial-average power density

TR technical report

### 3.3. Quantities

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

**Table 1: Quantities**

| Quantity | Symbol | Unit |
|---|---|---|
| Electric field strength | $E$ | volts per metre (V/m) |
| Magnetic field strength | $H$ | amperes per metre (A/m) |
| Power density | $S$ | watts per square metre (W/m$^2$) |

## 4. General requirements

As set forth in RSS-102, IPD compliance of portable devices shall be assessed against reference level limits. IPD compliance shall be demonstrated based on Health Canada's Safety Code 6 and its Safety Code 6 Notice limits adopted in RSS-102.

## 5. Simulation-based assessments

When a simulation-based assessment is allowed according to RSS-102.IPD.MEAS, it shall be carried out as per the requirements hereunder.

### 5.1. General

The general requirements associated with a computational modelling-based compliance approach are outlined in Annex C.

### 5.2. Computer-aided design model

The computer-aided design (CAD) model shall be in accordance with Annex D.

### 5.3. Computational software

The computational software shall be in accordance with Annex E.

### 5.4. Portable devices operating in the 60 GHz frequency band (57-71 GHz)

Refer to Annex F for IPD simulations on portable devices operating in the 60 GHz frequency band (57-71 GHz).

An inquiry shall be submitted for applications not operating in the 60 GHz frequency band (57-71 GHz).

### 5.5. Uncertainty budget evaluation

The uncertainty budget evaluation shall be completed in accordance with Annex G.

## 6. RF exposure technical brief

The RF exposure technical brief shall include all information required to reproduce the simulation and associated measurement results, including information related to the test configurations, methods and instrumentation. A comprehensive list of the required information is provided in Annex A of this document and in annex A of RSS-102.IPD.MEAS.

# Annex A Information to report for incident power density assessment (normative)

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 incident power density (IPD) limits for portable devices operating in the 60 GHz frequency band (57-71 GHz).

Section A.1 provides details on the information to report for simulations.

## A.1 Information to report for computational modelling

| |
|---|
| **(1) Computational resources** |
| • Summary of the computational resources used to perform the incident power density (PD) computations for the equipment under test (EUT) 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. equipment under test (EUT) 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 EUT model |
| **(4) Transmitter model implementation and validation** |
| • Description of the essential features that must be modelled correctly for the particular EUT model to be valid |
| • Descriptions and illustrations showing the correspondence between the modelled EUT and the actual device with respect to shape, size, dimensions and near-field radiating characteristics |

| |
|---|
| • Verification of the EUT 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 EUT 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 EUT test positions used in the PD computations |
| • Illustrations showing the evaluation surface and separation distances between the EUT 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 EUT 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 root mean square (RMS) E-field 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) |

# Annex B Specific information related to power density computations (normative)

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 $\phi$ and $\theta$ coordinates on the solid angle
- $\phi$ and θ are the coordinates on the solid angle in radians
- $E_{\phi r}$ and $E_{\phi i}$ are the real and imaginary parts of the $\phi$ component of the E-field
- $E_{\theta r}$ and $E_{\theta i}$ are the real and imaginary parts of the $\theta$ 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
- $|S_{11}|$ is the absolute value of the input reflection coefficient in dB

## Annex C Computational modelling (normative)

Computational techniques, such as finite-difference time-domain (FDTD), may be used to determine the configurations with the highest peak spatial-average power density (psPD) and spatial peak power density (pPD) for each test frequency. Measurements shall then be performed for these configurations as per section 5 of RSS-102.IPD.MEAS. 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 radio frequency (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 root mean square (RMS) E-field and H-field levels at the pPD locations on the evaluation surface

The applicant shall submit all information relevant to the modelling (see section A.1 of annex A), 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 (refer to section 5 of RSS-102.IPD.MEAS).

## Annex D Computer-aided design model requirements (normative)

The equipment under test (EUT) model used for the computations should be equivalent, and ideally identical, to the actual device that will be assessed with the measurement system. The computer-aided design (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 Radio Standards Procedure 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 (including any frequency dependencies) are identified. Whenever possible, all conducting parts should be integrated into the CAD model with their associated frequency-dependent dielectric properties.

Truncation of the EUT 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 radio frequency (RF) exposure technical brief that the truncation has a negligible impact on the RF characteristics of the EUT model.

## Annex E Computational software requirements (normative)

Software that meets the code verification requirements of IEC/IEEE 62704-1 may be used for the purpose of this document. The software shall be capable of determining the power density as defined in section 3.

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 radio frequency (RF) exposure technical brief (see “Algorithm implementation and validation” in Annex A).

# Annex F Portable devices operating in the 60 GHz frequency band (57-71 GHz) (normative)

The following sections are in addition to the general guidance provided in section 5.

## F.1 Computational assessment

The equipment under test (EUT) should be modelled in free-space and the testing configurations shall be chosen according to section C.1 of annex C of RSS-102.IPD.MEAS 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 EUT are not affected by absorbing boundary conditions.

A convergence study supporting the meshing parameters utilized shall be included for the chosen convergence criteria. The convergence and criteria/condition for simulation completion shall be provided in the radio frequency (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 peak spatial-average power density (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.

## F.2 Validation of the EUT CAD model

The EUT 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 $v_{sim}(n)$.
- The measured power density values at each position $n$ on the evaluation surface, obtained in accordance with section C.2 of annex C of RSS-102.IPD.MEAS, shall be normalized to the radiated power. These values are denoted as $v_{meas}(n)$.
- The numerical uncertainty $U_{PD}$ shall be used instead of $U_{SAR}$ for near-field evaluations and is determined by the following:

$$U_{PD}(\%) = 100 \cdot \max\left[\frac{|v_{meas}(n) - v_{sim}(n)|}{\max[v_{meas}(n)]}\right] \quad (5)$$

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

$$\xi_n = \sqrt{\frac{[v_{sim}(n) - v_{meas}(n)]^2}{\left[v_{sim}(n) \cdot U_{sim(k=2)}\right]^2 + \left[v_{meas}(n) \cdot U_{meas(k=2)}\right]^2}} \leq 1 \qquad (6)$$

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

# Annex G Uncertainty evaluation (normative)

The evaluation of the measurement and computational uncertainty budget is outlined in sections G.1 and G.2, respectively.

## G.1 Measurement uncertainty budget evaluation

A measurement uncertainty budget shall be completed in accordance with RSS-102.IPD.MEAS.

## G.2 Computational uncertainty budget evaluation

The applicant shall provide a computational uncertainty budget. The detailed table on uncertainty budgets found in section 7.4 of IEC/IEEE 62704-1 may be used to calculate the numerical uncertainty budget with the following changes:

- The evaluation of the phantom dielectrics shall be replaced by an evaluation of the dielectric parameters of the equipment under test (EUT).
- The impact of lossy conductors shall be evaluated. This may be done by evaluating the minimum and maximum conductivity of all conductors of the EUT 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.