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RSS-102.IPD.MEAS
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Spectrum Management and Telecommunications

Radio Standards Specification

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

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Preface

Radio Standards Specification RSS-102.IPD.MEAS, *Measurement 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 measurement procedures are consolidated into this document to simplify the identification of procedures related to IPD testing based on measurements.

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

1. requirements for simulation are now located in RSS-102.IPD.SIM, *Simulation 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

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Director General
Engineering, Planning and Standards Branch

Contents

1. Scope

This Radio Standards Specification (RSS) sets out the general test 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 measurement-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.MEAS is limited to the assessment of portable devices operating in the 60 GHz frequency band (57-71 GHz) using an approach based on measurements or a combined approach based on measurements and simulations. 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.MEAS 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.MEAS, issue 1, or RSS-102.IPD.SIM, *Simulation 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.MEAS 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 certificationbureau-bureauhomologation@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 $L = \sqrt{A_{avg}}$. 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-field 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): 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:

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

Reconstruction algorithm: The 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:

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

where:

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

- T is the averaging time

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

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

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

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

SAM specific anthropomorphic mannequin
SAR specific absorption rate
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.

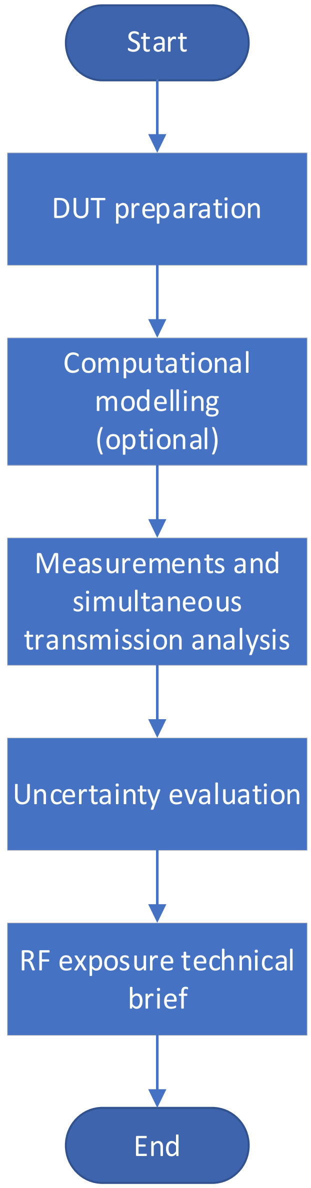
5. Measurement-based assessments

This section sets out the requirements applicable to radio transmitters subject to this standard. Section 5.1 outlines the general approach to measurement-based IPD evaluation. Guidance for specific applications is provided in section 5.2 and section 5.3. Guidance for assessments requiring simulations is provided in section 5.4.

5.1. IPD evaluation methods

The steps for IPD assessment of portable devices are summarized in Figure 1. The assessment approach is based on annex G of IEC TR 63170 as referenced in section 2.

Figure 1: Summary of the assessment approach to assess compliance of portable devices to IPD limits



When practical, all device antenna configurations should be measured during an IPD assessment. However, an approach based on near-field simulations and measurements is permitted when the number of possible antenna configurations is large.

Simulations can be employed to determine worst-case antenna configurations followed by measurements of the worst-case configurations. This approach has two main advantages:

1. It reduces the number of configurations requiring measurements.
2. Measurements validate simulation results.

Each step in the assessment approach is outlined in the following subsections.

5.1.1. Equipment under test preparation

Equipment under test (EUT) preparation shall be in accordance with Annex B.

5.1.2. Computational modelling (optional)

Computational assessment methods are described in RSS-102.IPD.SIM.

5.1.3. Measurements and simultaneous transmission analysis

Measurements and simultaneous transmission analysis shall be in accordance with Annex C.

5.1.4. Uncertainty evaluation

The uncertainty evaluation shall be completed in accordance with Annex D.

5.1.5. RF expolsure technical brief

Details for the RF exposure technical brief are included in section 6.

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

Refer to Annex E for IPD measurements on portable devices operating in the 60 GHz frequency band (57-71 GHz). The general approach outlined in section 5.1 shall be followed with the additional guidance provided in Annex E.

5.3. Portable devices not 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).

5.4. Simulation-based assessments

When the practical limitations of the test equipment or tissue-equivalent phantom prohibit a measurement-based assessment, a simulation (computational) assessment against the basic restrictions may be performed.

Computational assessment methods are described in RSS-102.IPD.SIM.

6. 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.

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 **Error! Reference source not found.** provides details on the information to report for measurements.

A.1 Information to report for measurements

(1) Measurement system and site description
• Brief description of the power density (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
(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, spatial peak power density (pPD) and peak spatial-average power density (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 Equipment under test preparation (normative)

The preparation of the equipment under test (EUT) is based on the principles set forth in IEC TR 63170. The evaluation surface, test position, test frequencies and configurations shall be determined when performing the compliance assessment.

B.1 Test positions and evaluation surfaces

The test position(s) of the EUT for power density assessment shall be based on those specified in RSS-102.SAR.MEAS, *Measurement Procedure for Assessing Specific Absorption Rate (SAR) Compliance in Accordance with RSS-102*, for specific absorption rate (SAR) measurements. Other ISED-recognized procedures such as the knowledge database (KDB) procedures relating to radio frequency (RF) exposure published by the Federal Communications Commission (FCC) are also applicable. A complete list of accepted procedures can be found on ISED's Certification and Engineering Bureau website.

The rationale, including a description of the evaluation surfaces and test positions, shall be provided in the RF exposure technical brief (see section 6).

B.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.

B.3 Configurations to be tested

In general, the EUT 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 EUT.

B.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 for each applicable combination of amplitude and phase excitations. These field strength values are employed to derive the corresponding spatial peak power density (pPD) and peak spatial-average power density (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.

B.5 Devices with elements that do not operate simultaneously

Assessments shall be performed for each active antenna element. The assessment shall determine the electric and magnetic field strengths on the evaluation surfaces corresponding to each test position. 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.

Additional considerations apply if the EUT employs uncorrelated signals in different frequency bands. Refer to section C.5.3 of annex C for additional guidance.

Annex C Measurements (normative)

This section contains detailed information on measurements and simultaneous transmission analysis.

C.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 RSS-102.IPD.MEAS will be able to demonstrate that background noise is addressed in accordance with good engineering practices.

C.2 Measurement equipment

The measurement system must be capable of assessing near-field peak spatial-average power density (psPD) and spatial peak power density (pPD) on the evaluation surface by performing near-field and/or far-field measurements, with known uncertainty, in the operating frequency range of the equipment under test (EUT).

The measurement system shall be capable of measuring the E-field and/or H-field, 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 employed 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, above.

C.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 RSS-102.IPD.MEAS.

C.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).

C.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:

$$\Delta psPD_{target} = \left| 10 \cdot \log\left(\frac{psPD_{meas}}{psPD_{target}}\right) \right| \qquad (5)$$

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:

$$u_{combined} = \sqrt{u_{cal\_ant}^2 + u_{rad\_power}^2 + u_{meas}^2} \qquad (6)$$

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:

$$\Delta psPD_{reference} = \left| 10 \cdot \log\left(\frac{psPD_{meas}}{psPD_{reference}}\right) \right| \quad (7)$$

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:

$$u_{relative} = \sqrt{u^2_{power_{relative}} + u^2_{meas_{relative}}} \quad (8)$$

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 EUT measurements.

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

C.4 EUT set-up for measurements

The EUT 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 EUT 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 EUT, 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 EUT shall be configured 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 EUT 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 an EUT 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. Sections 6.1.3.2 of IEC 62209-2 and 6.4.3

of IEC/IEEE (Institute of Electrical and Electronics Engineers) 62209-1528, although intended for specific absorption rate (SAR), provides further guidance.

C.5 Power density measurement

This section contains detailed information on power density measurements.

C.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:

$$\eta = \frac{E}{H} \tag{9}$$

$$S_{eq} = \frac{E^2}{\eta} = H^2\eta \tag{10}$$

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 ($377\ \Omega$)

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:

$$S_{avg} = \frac{1}{2\eta A_{avg}} \iint_{A_{avg}} |E|^2 dA = \frac{\eta}{2A_{avg}} \iint_{A_{avg}} |H|^2 dA \tag{11}$$

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} occurs is considered to be 1.6λ. When D is between $\lambda/3$ and 2.5λ, the distance where S_{eq} occurs is considered to be $5D$. When D is greater than 2.5λ, the distance where S_{eq} occurs is considered to be $2D^2/\lambda$.

C.5.2 Evaluation surface in the near-field region

Generally, the power density assessment will be close to the EUT 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. Deviations related to these steps are provided below:

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 EUT. The drift may be calculated using the following formula:

$$Power\ drift = \left|\frac{Ref_1^2 - Ref_2^2}{Ref_1^2}\right| \cdot 100\% \qquad (12)$$

    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 EUT and documented in the RF exposure technical brief.

C.5.3 Measurement of devices with multiple antennas or multiple transmitters

All EUT operation modes capable of multiple simultaneous transmissions, including those outside of the range of this document, shall be tested in accordance with RSS-102.

Annex D Uncertainty evaluation (normative)

This annex contains detailed information on the evaluation of the measurement-based uncertainty budget.

D.1 General

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:
  - frequency response
  - sensor cross-coupling
  - field impedance dependence
  - readout electronics
  - response time of the field probes
    - 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

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

This annex contains detailed information on the assessment of portable devices operating in the 60 GHz frequency band (57-71 GHz).

E.1 Equipment under test preparation

The equipment under test (EUT) shall be prepared in accordance with section 5.1.1 and the following subsections.

E.1.1 Test positions and evaluation surfaces

The test position(s) of the EUT shall be based on those specified in RSS-102.SAR.MEAS, *Measurement procedure for assessing specific absorption rate (SAR) compliance in accordance with RSS-102*. Two main EUT form factors are described as follows:

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 EUT must be evaluated unless they meet the exclusion criteria accepted by ISED. For measurements, 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 employed. It shall be demonstrated that the chosen tangential plane produces conservative peak spatial-average power density (psPD) and spatial peak power density (pPD) values. However, the differences in the planes used for evaluations (SAM phantom for specific absorption rate (SAR) and evaluation surface tangential for power density) will introduce challenges combining exposure levels for simultaneous transmissions in accordance with section C.5.3 of annex C. 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 6).