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Radio Standards Specification

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

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Canada

Preface

Radio Standards Specification RSS-102.IPD.SIM, *Simulation Procedure for Assessing Incident Power Density (IPD) Compliance in Accordance with RSS-102,* issue 2, replaces RSS-102.IPD.SIM, issue 1, dated December 2023.

The main changes are listed below:

1. **new** requirements extending the frequency range to cover all portable devices operating in the 6 GHz to 300 GHz frequency band
2. **updated** the assessment requirements reference to IEC/IEEE 63195-2; and
3. 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

Additional information and guidance are available on the Innovation, Science and Economic Development Canada (ISED) webpages Common Questions and Answers and General Notices.

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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Martin Proulx
Director General
Engineering, Planning and Standards Branch

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1. Scope

This Radio Standards Specification (RSS) sets out the computational electromagnetics simulation methods for assessing compliance of portable equipment operating in the frequency range from 6 GHz to 300 GHz frequency band with incident power density (IPD) limits as specified in RSS-102, *Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)*.

1.1. Purpose and application

In accordance with section 7.5 of RSS-102, RSS-102.IPD.SIM outlines the requirements for computational electromagnetics simulation based assessments of devices subject to incident power density (IPD) compliance limits. Note that in this document, the terms computational and simulation are being used interchangeably; they all refer to computational electromagnetics simulations.

The annexes of RSS-102.IPD.SIM are normative. References to other documents or annexes in other documents are normative as well.

RSS-102.IPD.SIM covers all portable devices operating in the 6 GHz to 300 GHz frequency band. The technical requirements contained in it are used to perform accurate and repeatable simulation-based assessments.

1.2. Transition period

This document 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 6 months from the publication date will be provided, within which compliance with the IPD provisions in, RSS-102.IPD.SIM, issue 1, and RSS-102.IPD.SIM, issue 2, will be accepted. After this period, only applications for the certification of equipment under the provisions of RSS-102.IPD.SIM, issue 2, will be accepted. Furthermore, after this transition period, equipment that is manufactured, imported, distributed, leased, offered for sale, or sold in Canada shall comply with RSS-102.IPD.SIM, issue 2.

A copy of RSS-102.IPD.SIM, 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. To this end, 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

Refer to RSS-102 and RSS-102.IPD.MEAS for the abbreviations/acronyms and quantities which are applicable to this standard.

4. General requirements

This section outlines the general requirements for compliance assessment of EUT operating from 6 GHz to 300 GHz.

4.1. Exposure limits, use cases and exposure conditions

Radiocommunication apparatus shall comply with the limits outlined in Health Canada's Safety Code 6 and its Safety Code 6 Notice adopted in RSS-102. Refer to section 5 of RSS-102 for the relevant limits.

> As per Health Canada's Safety Code 6 and its Notice, for the 6 GHz to 300 GHz frequency band, two frequency-dependent limits are defined.
>
> The first limit applies to frequencies above 6 GHz and up to 300 GHz; it is associated with an averaging area defined as a $4\ cm^2$ square.
>
> The second limit, which is twice the first limit, applies to frequencies above 30 GHz; it is associated with a spatial peak (pIPD) that is not averaged over an area.
>
> Note that for frequencies above 30 GHz, other international RF exposure guidelines allow an **averaging area of 1 cm^2**. This **is <u>not</u> permitted in Safety Code 6 and its Notice.**

It is important to note that compliance in the reactive near-field zone would normally be made against the absorbed power density (BR) limits. However, as ISED has not yet developed RSS-102.APD, compliance of portable devices operating from 6 GHz to 300 GHz shall be assessed against the IPD (RL) limits in 5.3.3 of RSS-102. This situation is only expected for transmitters that operate below 24 GHz.

Use-cases and operating configurations shall be identified and described in the RF exposure technical brief (see section 6 of this document). It shall be clear how the user and/or bystander foreseeably interacts with the EUT. Key RF exposure conditions shall be identified using this information. The exposure assessment shall demonstrate compliance with the applicable limits for each exposure condition.

5. Simulation-based assessments

The simulation-based assessment shall be conducted as per IEC/IEEE 63195-2.

5.1. Computational tool and method

The computational tool used for assessments shall be clearly identified in the RF exposure technical brief. Ideally, it should employ one of the following full-wave computational methods:

- finite difference time domain (FDTD)/ finite integration technique (FIT)
- finite element method (FEM)

If a different computational method from the ones identified above is being considered, an inquiry form (directed to the Directorate of Regulatory Standards) shall be submitted to ISED, which describes the proposed method and how it can be used to perform a conservative RF exposure assessment.

5.2. Code verification

The selected computational tool shall meet the code verification requirements outlined in Annex A of IEC/IEEE 63195-2.

5.3. Computational model

This section provides the requirements related to the computational model.

The applicant shall submit all information relevant to the modelling (see Annexes A to C), 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).

5.3.1. EUT model

The EUT shall be modelled in free-space and the testing configurations shall be chosen according to section 5.3 of RSS-102.IPD.MEAS and modelled appropriately.

The procedure for modelling the EUT shall be described in the RF exposure technical brief. Relevant mechanical dimensions and material properties shall be provided, along with the associated tolerances.

Truncation of the EUT model or computational domain is allowed in order to reduce computational resources. However, the reactive fields of the model should not be truncated. 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. The methodology in section 9.2.5 of IEC/IEEE 63195-2 can be used in that regard.

5.3.2. Evaluation surface

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.

The averaging of the IPD on an evaluation surface shall be performed in accordance with section 8.4 of IEC/IEEE 63195-2.

5.3.3. Simulation parameters and computational resources

All relevant simulation parameters, such as those related to the meshing, boundary conditions, convergence, etc., as well as the computational resources required to reproduce the simulation results, shall be provided in the RF exposure technical brief.

5.3.4. Uncertainty analysis

This section provides the requirements related to computational uncertainty analysis.

5.3.4.1. General requirements

A complete uncertainty analysis shall be conducted and presented in accordance with IEC/IEEE 63195-2. The uncertainty budget, which shall be provided in the RF exposure technical brief, shall demonstrate that the expanded uncertainty (k = 2) of the computational model is below 30 %.

The steps taken in evaluating each component of the uncertainty budget shall be provided in the RF exposure technical brief.

5.3.4.2. Simulation uncertainty

Deviations from the prescribed procedures for evaluating the various simulation uncertainties may be necessary. For example,

a. Mesh resolution (FDTD/FIT): If the requirements provided in section 9.2.2.2 of IEC/IEEE 63195-2 are too computationally burdensome, this uncertainty may instead be evaluated by increasing the total number of mesh cells by a factor of 2 or, when applying sub-gridding, by a factor of 4 in the region of highest exposure (including the source antenna(s)).

b. Boundary conditions (FDTD/FIT/FEM): If the requirements provided in section 9.2.3. of IEC/IEEE 63195-2 are too computationally burdensome, this uncertainty may instead be evaluated by increasing the size of the bounding box by 50% in all directions.

c. Convergence (FDTD/FIT): If the requirements provided in section 9.2.6 of IEC/IEEE 63195-2 are too computationally burdensome, the following may be applied.

   The simulation time required for convergence, T_{conv}, shall be long enough to ensure that the maximum root-mean-square (RMS) field level remains in the same voxel when the simulation time is increased to 1.5 T_{conv} (i.e. that the location of the maximum RMS field level does not change). In addition, the field level associated with this voxel shall not change by more than 2%. Either the E- or H-field may be considered, whichever is dominant in the context of exposure. The percent change in the maximum RMS field level when increasing from T_{conv} to 1.5 T_{conv} shall be taken as the convergence uncertainty, with a rectangular distribution.

5.3.4.3. EUT model uncertainty and validation

A complete uncertainty analysis involves performing measurements to validate the EUT model and determine its uncertainty.

The uncertainty component EUT model (as shown in Table 2 of IEC/IEEE 63195-2) may be calculated in accordance with section 9.3 in IEC/IEEE 63195-2.

In situations where the IPD value derived from E- and/or H-field, the uncertainty may be evaluated according to section 9.3 in IEC/IEEE 63195-2.

$$U_{IPD}(\%) = 100 \cdot \max(\mathrm{n}) \left[\frac{|{v^2}_{meas}(n) - {v^2}_{sim}(n)|}{\max\{\max(n)\,|{v^2}_{meas}(n)|\,,\ \max(n)\,|{v^2}_{sim}(n)|\}} \right] \quad (1)$$

Where

- $v_{meas}(n)$ is the IPD value derived from E- and/or H-field from *measurements* at position *n* or its accurate reference solution;

- $v_{sim}(n)$ is the IPD value derived from E- and/or H-field from *simulations* at position *n*;

The uncertainty of the EUT model based on direct IPD values may be evaluated as follows:

- 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 5 of RSS-102.IPD.MEAS, shall be normalized to the radiated power. These values are denoted as $v_{meas}(n)$.

- The numerical uncertainty U_{IPD} shall be used instead of U_{SAR} for near-field evaluations and is determined by the following:

$$U_{IPD}(\%) = 100 \cdot \max \left[\frac{|v_{meas}(n) - v_{sim}(n)|}{\max[v_{meas}(n)]} \right] \quad (2)$$

The impact of lossy conductors shall be evaluated. This shall 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 according to Annex C of IEC/IEEE 63195-2.The computational EUT model shall be validated by measurements. The requirements for the successful validation of simulation results against the corresponding measurement data is specified below. The EUT model validation shall be calculated in accordance with section 7.5.3 in IEC/IEEE 63195-2. Specifically:

If the EUT model validation is based on IPD values derived from the E- and H-fields, this may be evaluated as follows:

- 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:

$$\xi_n = \sqrt{\frac{[v_{sim}(n) - v_{meas}(n)]^2}{\left[v_{sim}(n) \cdot U_{sim(k=2)}\right]^2 + \left[v_{meas}(n) \cdot U_{meas(k=2)}\right]^2}} \leq 1 \quad (3)$$

Where

- $v_{meas}(n)$ is the experimentally determined IPD at position *n* or its accurate reference solution;
- $v_{sim}(n)$ is the computationally determined IPD at position *n*;
- $U_{sim(k=2)}$ is the expanded (k = 2) uncertainty of the simulated value; and
- $U_{meas(k=2)}$ is the expanded (k = 2) uncertainty of the measured value

If the EUT model validation is instead based on <u>direct</u> IPD values, the calculation becomes:

$$\xi_n = \frac{(IPD_{meas} - IPD_{sim})}{\sqrt{(U_{meas} \cdot IPD_{meas})^2 + (U_{sim} \cdot IPD_{sim})^2}} \leq 1 \quad (4)$$

where:

- ξ_n is the normalized deviation
- IPD_{meas} is a single measured IPD value
- IPD_{sim} is a single simulated IPD value
- U_{meas} is the expanded (k = 2) uncertainty of the measured value
- U_{sim} is the expanded (k = 2) uncertainty of the simulated value

Note that IPD_{meas} and IPD_{sim} shall be at the same location and configuration.

When $\xi > 1$, using formula (3) or (4), the EUT model is not within the combined standard uncertainty. The EUT model shall be revised and reassessed until $\xi \leq 1$.

A detailed description of the EUT model validation procedure shall be provided in the RF exposure technical brief, along with model validation results and plots or tables demonstrating agreement between measured and simulated results.

5.4. Exposure assessments

Once the computational model has been validated, exposure assessments can be performed. This section provides the requirements in this regard.

5.4.1. Exposure scenarios and separation distances

Assessments shall be performed for each exposure scenario and separation distance identified in sections 4.1 and 4.2 of RSS-102.IPD.MEAS, respectively, unless sufficient rationale is provided for a reduced set of worst-case exposure scenarios and separation distances in the RF exposure technical brief.

Assessment using all the relevant IPD exposure metrics (i.e. $sIPD_{n+}$, $sIPD_{mod+}$, $sIPD_{tot+}$, and psIPD) shall be reported, including the pIPD for EUT with elements operating above 30 GHz.

5.4.2. Devices with multiple antennas or multiple transmitters

For devices with elements that do not operate simultaneously, assessments shall be performed for each active antenna element as specified in section 8.2.2 of IEC/IEEE 63195-2. Note that the pIPD shall also be evaluated and reported following section 8.2.2 of IEC/IEEE 63195-2 for EUT operating above 30 GHz.

Additional assessments shall be performed for devices with multiple uncorrelated antennas or multiple transmitters or sources that operate independently and can operate in different frequency ranges. Their exposure shall be combined and reported in terms of the total exposure ratio, as mentioned in section 8 of RSS-102.

5.4.3. Devices with arrays or sub-arrays

For devices with arrays or sub-arrays, assessments shall be performed for each active array or sub-array following section 8.2.3 of IEC/IEEE 63195-2. For all EUT, the $sIPD_{n+}$, $sIPD_{mod+}$, $sIPD_{tot+}$, and for EUT operating above 30 GHz pIPD, shall be computed separately and reported in the RF exposure technical brief for each RF channel and for each antenna. The psIPD shall then be computed by applying maximization techniques specified in Annex C of IEC/IEEE 63195-2. A description, including the rationale and uncertainty associated with the chosen maximization technique, shall be documented in the RF exposure technical brief.

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.

Refer to annex A of RSS-102 for additional information.

Annex A Information to report for incident 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 incident power density (IPD) limits for portable devices operating in the 6 to 300 GHz frequency band.

Section A.1 lists information on the test device and exposure category. Section A.2 lists specific information for incident power density (IPD) simulations.

A.1 Information on the test device and exposure category

(1) General information
• ISED certification ID
• Information related to certification (i.e. HVIN, PMN, HMN, etc.)
• Model number
• RF Exposure environment (general public/controlled use)
(2) Description of the equipment under test (EUT)
• Nature and intended purpose of the EUT
• Theory of operation of the EUT
(3) Device operating configurations and test conditions
• Brief description of the test device operating configurations, including:
○ illustration(s) of the antenna position(s) relative to the equipment under test, including dimensions and separation distances (for multiple transmitters/antennas), as applicable
○ operating mode(s) and operating frequency range(s)
○ maximum output power of the device for each operating mode and frequency range
○ maximum tune-up tolerances (i.e. variation in output power of the applicable test channels)
○ antenna type with gain and operating positions
○ applicable head, body-worn, body-supported and/or limb-worn configurations
○ battery options that could affect the IPD results
○ description of the test mode software including the version number and what the software was used to control or configure as applicable (including, but not limited to, antenna selection, signaling, power tables, dynamic antenna tuning, control time-averaged IPD algorithm parameters, etc.)
• Procedures used to establish the test signals
• Detailed description of the communication protocols used during the evaluation
• Maximum output power or local IPD measured before and after each IPD test

• Description of the scaling factor used, as applicable
• Description of the waveforms generated by each transmitter within the EUT, including the fundamental wave shape (sinusoidal, triangular, rectangular or otherwise) and frequency, applied modulation and 99% occupied bandwidth (OBW), duty factor, etc.
• Description of the conducted power of excitation level applied to each antenna based on applicable use-cases and operating states

A.2 Information to be included in the RF exposure technical brief regarding computational assessments

(1) Computational resources
• Computational tool and method (i.e. FDTD/FIT and FEM)
• Code verification results (may be included in a separate attachment)
• Summary of the computational resources used to perform the incident power density (IPD) 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 IPD 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 IPD evaluation
(3) Computational parameters
• Tabulated list of computational parameters such as:
1. Total 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 IPD 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
• Description of truncated model, if applicable, and rationale and demonstration that the truncation has a negligible impact on the RF characteristics of the EUT model
• Verification of the EUT model to ensure its equivalency with the actual device in predicting the IPD distributions
• Verification of the IPD distribution at the high, middle and low channels, similar to those considered in IPD measurements for determining the highest IPD
(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 IPD 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 IPD computations
• Illustrations showing the evaluation surface and separation distances between the EUT model and the measurement system for the tested configurations
• Detailed description of the exposure assessment procedure and results, including all exposure conditions and separation distances, with rationale for reduction to the worst-case configurations
(8) Computing spatial peak incident power density from field components
• Description of the procedures used to compute the sinusoidal steady-state peak E-fields, H-fields, and pIPD on the evaluation surface
• Description of the procedures used to search for the highest spatial peak incident power density (pIPD)
• Description of the expected error margin provided by the algorithms used to compute the IPD 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 pIPD
(9) Peak spatial-average incident power density procedures
• Description of the procedures used to search for the highest peak spatial-average incident power density (psIPD), 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 psIPD
(10) Total computational uncertainty
• Complete uncertainty budget in accordance with 63195-2
• Description of how each uncertainty value was obtained, including any deviations from the above standard
• Detailed description and illustration of the EUT model validation procedure and results
• Statement of the expanded uncertainty, which shall be ≤ 30%
(11) Computational results
• Description of how the maximum device output rating is determined and used to normalize the IPD values for each test configuration
• Plots of the IPD on the evaluation surface, both before and after spatial averaging is applied, for each test configuration to be measured
• Tabulated list of the pIPD and psIPD 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 pIPD location
• Description of applied method to evaluate psIPD (e.g. field maximization technique, optimization, codebook, etc.)
• Description of applied averaging algorithm according to section 8.6 of IEC/IEEE 63195-2
(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

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 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
- $|S_{11}|$ is the absolute value of the input reflection coefficient in dB

Annex C Computer-aided design model requirements

The equipment under test (EUT) model used for the computations should be equivalent, and ideally identical, to the actual device that would 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, *.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.