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RSS-102.NS.MEAS
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Spectrum Management and Telecommunications

Radio Standards Specification

Measurement Procedure for Assessing Nerve Stimulation (NS) Compliance in Accordance with RSS-102

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Canada

Preface

This Innovation, Science and Economic Development Canada (ISED) radio standard describes the technical requirements and assessment procedures for demonstrating compliance of radio apparatus with the radiofrequency (RF) exposure limits outlined in RSS-102, *Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)*, from 3 kHz to 10 MHz. It applies to all radio apparatus producing RF emissions in this range. It also applies to some interference-causing equipment, specifically Industrial, Scientific and Medical (ISM) equipment.

Radio Standards Specification RSS-102.NS.MEAS, issue 1, *Assessing NS Compliance in Accordance with RSS-102,* replaces Supplementary Procedure SPR-002, issue 2, *Supplementary Procedure for Assessing Compliance of Equipment Operating from 3 kHz to 10 MHz with RSS-102*, dated October 2022.

This document is associated with the modernization of RSS-102, *Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)*. All nerve stimulation (NS)-related measurement procedures are consolidated into this document to simplify the identification of procedures related to NS testing.

The content is nearly identical to SPR-002 issue 2, with the following exceptions:

1. requirements for simulation are now located in RSS-102.NS.SIM, *Simulation Procedure for Assessing Nerve Stimulation (NS) Compliance in Accordance with RSS-102.*

2. requirements for specific absorption rate (SAR)-related measurements are now located in RSS-102.SAR.MEAS, *Measurement Procedure for Assessing Specific Absorption Rate (SAR) Compliance in Accordance with RSS-102*

3. requirements for SAR-related simulations will be located in RSS-102.SAR.SIM (currently in development)

4. requirements for calculation of the uncertainty are clarified

5. requirements for table top devices are clarified

6. 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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Martin Proulx
Director General
Engineering, Planning and Standards Branch

Contents

1. Scope

This Radio Standards Specification (RSS) sets out the measurement methods for assessing compliance of equipment operating in the frequency range from 3 kHz to 10 MHz with the radio frequency (RF) exposure limits to prevent nerve stimulation (NS) as outlined in RSS-102, *Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)*.

The requirements within this document also apply to wireless power transfer (WPT) source subassemblies, including Type 1, which are classified as interference-causing equipment.

1.1. Purpose and application

RSS-102.NS.MEAS provides general requirements for measurement-based assessments of RF exposure in the range of 3 kHz to 10 MHz, as well as the combination of exposure contributions from multiple transmitters and/or multiple frequencies.

At times, specific absorption rate (SAR)-related compliance measurements are introduced for comprehensive context and completeness. SAR-related compliance measurements are covered in RSS-102.SAR.MEAS, *Measurement Procedure for Assessing Specific Absorption Rate (SAR) Compliance in Accordance with RSS-102*.

The annexes of RSS-102.NS.MEAS are normative, providing additional requirements related to spatial averaging and assessment methods for wireless power transfer (WPT) implementations (e.g. to enable portable device or electric vehicle (EV) charging) as well as a variety of common device types (e.g. enabling electronic article surveillance, metal detection, radiofrequency identification, tire pressure monitoring and vehicle security).

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 12 months from the publication date will be provided, within which compliance with the NS provisions in SPR-002, issue 2, *Supplementary Procedure for Assessing Compliance of Equipment Operating from 3 kHz to 10 MHz with RSS-102*, RSS-102.NS.MEAS, issue 1 or RSS-102.NS.SIM, issue 1, *Simulation Procedure for Assessing Nerve Stimulation (NS) Compliance in Accordance with RSS-102* will be accepted. After this period, only applications for certification of equipment using RSS-102.NS.MEAS, issue 1 or RSS-102.NS.SIM, issue 1, will be accepted and equipment manufactured, imported, distributed, leased, offered for sale, or sold in Canada, shall comply with this issue.

A copy of SPR-002, issue 1, may be requested 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.NS.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 definitions apply to this standard.

Evaluation surface: The surface upon which incident fields are evaluated in assessments against the reference levels.

Exposure region: The region in space over which an RF exposure assessment is performed. For assessments against the basic restrictions, the exposure region corresponds to the volume of space that would be occupied by a tissue-equivalent phantom, whereas for assessments against the reference levels, it corresponds to the evaluation surface.

Far-field (region): The space around an antenna or other radiating structure where the angular field distribution begins to be essentially independent of the distance from the antenna. In this space, the field has a predominantly plane-wave character. Refer to TN-261, *Safety Code 6 (SC6) Radio Frequency Exposure Compliance Evaluation Template (Uncontrolled Environment Exposure Limits)*, for further details regarding antenna field regions.

Instantaneous root-mean-square (RMS) value: The square root of the average of the square of the instantaneous waveform amplitude taken throughout one period of the waveforms generated by a transmitter of the equipment under test (EUT).

Maximum instantaneous root-mean-square (RMS) value: The temporal maximum instantaneous RMS value.

Near-field (region): The volume of space surrounding an antenna or other radiating structure in which the electric and magnetic fields do not have a substantially plane-wave character, but vary considerably from point to point at the same distance from the source. Refer to TN-261, for further details regarding antenna field regions.

Power transfer management: Capability of some WPT devices to exchange information related to the power transfer operation between the source and client devices for purposes such as detecting invalid client devices or objects, communicating status information, sending commands from the source to the client, and sending acknowledgements from the client to the source.

Reactive near-field (region): The sub-region within the near-field region of an antenna or other radiating structure where evanescent fields are dominant. The reactive near-field region extends to a distance of at least $\lambda/2\pi$ from the antenna, where λ is the wavelength in metres. Refer to TN-261 for further details regarding antenna field regions.

Table top device: A transmitting device designed to be used on a table. It is powered through an electrical connection to an alternating current (AC) mains supply.

Wireless power transfer (WPT): The transfer of energy from one or more source devices to one or more client devices through electromagnetic waves or fields using magnetic field (inductive or resonant), electric field (capacitive or resonant), or radiative means, with no electrical contact between the source device(s) and client device(s), for the purpose of powering and/or charging the client device(s) wirelessly.

WPT client: A device capable of receiving power wirelessly from a WPT source.

WPT source: A device directly connected (i.e. through a wired connection) to a power source(e.g. AC mains, a battery or some other source of internal or external electrical power), which is capable of wireless power transfer to one or more WPT clients.

3.2. Abbreviations/acronyms

This document uses the following abbreviations and acronyms:

EMF	Electromagnetic field
EUT	Equipment under test
EV	Electric vehicle
FFT	Fast Fourier transform
HMN	Host marketing name

HVIN Hardware version identification number
ISED Innovation, Science and Economic Development Canada

NS Nerve stimulation

OBW Occupied bandwidth

PMN Product marketing name
RBW Resolution bandwidth
RF Radio frequency
RMS Root-mean-square

SAR Specific absorption rate

WPT Wireless power transfer

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**
Magnetic flux density	B	tesla (T)
Electric field strength	E	volts per metre (V/m)
Frequency	f	hertz (Hz)
Magnetic field strength	H	amperes per metre (A/m)
Specific absorption rate	SAR	watts per kilogram (W/kg)
Wavelength	λ	metre (m)

4. General requirements

This section outlines the general requirements for compliance assessment of EUTs operating from 3 kHz to 10 MHz.

4.1. Exposure limits, use cases and exposure conditions

Radiocommunication apparatus shall comply with the limits outlined in Health Canada's Safety Code 6, which are adopted in RSS-102. Type 1 WPT sources, classified as interference-causing equipment shall also comply with the limits outlined in Health Canada's Safety Code 6. For RF emissions in the frequency range of 3 kHz to 10 MHz, compliance with the limits to prevent NS shall be demonstrated. These include the basic restriction for internal electric field strength (internal E-field), and the NS-based reference levels for incident electric- and magnetic-field strength (E-field and H-field).

Above 100 kHz, compliance with the limits to prevent thermal effects shall also be demonstrated in accordance with RSS-102.SAR.MEAS. It will also be in accordance with RSS-102.SAR.SIM, which is currently in development.

Use-cases and operating configurations shall be identified and described in the RF exposure technical brief. 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 objective of the exposure assessment is to demonstrate compliance with the applicable limits for each exposure condition.

4.2. Separation distance

The separation distance is the minimum distance between the EUT and the nearest surface of the exposure region of a user and/or bystander (i.e. the region over which RF exposure is to be evaluated). It is based on both the key RF exposure conditions identified in section 4.1 and the nature of the exposure limit under consideration. The limits to prevent NS are based on instantaneous exposure, while the limits to prevent thermal effects are based on average exposure over any six-minute period. Consequently, the NS- and SAR-based separation distances may be different.

Each separation distance applied during the assessment(s) shall be clearly identified in the RF exposure technical brief for each exposure type. In addition, the minimum separation distance to prevent NS shall be provided in the user manual to ensure safe installation and operation of the EUT.

When performing an assessment against the NS-based limits, the separation distance shall correspond to the shortest distance that can be reasonably maintained between the EUT and user/bystander at all times during EUT operation. If the user interacts directly with the EUT (e.g. portable devices or wireless chargers) the assessment shall be conducted at touch position (0 mm).

Larger separation distances may be considered in applications where the EUT is not accessible to untrained personnel, or special measures have been taken to prevent direct user interaction during EUT operation. In such cases a General Inquiry form shall be sent to ISED with clear and sufficient rationale for the chosen separation distance.

4.3. Operational description of the EUT

This section outlines requirements related to the operational description of the EUT that should be included in the RF exposure technical brief where applicable.

4.3.1. Operational description

The nature, intended purpose and theory of operation of the EUT shall be described.

4.3.2. Antennas

A description of each antenna (i.e. radiating or coupling element(s)), within the EUT shall be provided. When applicable, the following shall be provided:

- the number of antenna elements
- the element type (e.g. dipole, loop/coil, etc.)
- all relevant dimensions, including location(s) within the EUT, and distances to the outer surfaces of the enclosure(s)
- any other relevant details (e.g. the number of turns for a given coil, etc.)

4.3.3. Transmit waveforms

The waveforms generated by each transmitter within the EUT shall be described. Key details to include are:

- baseband, carrier or pulse (basis) wave shape (e.g. sinusoidal, triangular or rectangular)
- associated fundamental, carrier or pulse repetition frequency
- duty factor for pulsed waveforms

If multiple fundamental, carrier or pulse repetition frequencies are employed simultaneously, the above details shall be provided for each. Alternatively, if the fundamental, carrier or pulse repetition frequencies or amplitude of the field are variable over time, the corresponding frequency range shall be stated, and the relationship between the frequency at a given time instant and the factor(s) upon which it depends (e.g. the operating state(s)), shall be described.

4.3.4. Operating states

The behaviour of the EUT in each operating state (e.g. start-up, standby, etc.) shall be described. Of particular interest are the necessary conditions to trigger a state transition, and the associated timings.

4.3.5. Conducted power or excitation levels

The conducted power or excitation level (current or voltage) applied to each antenna shall be described based on the operating state and use-case. At a minimum, the nominal and maximum values shall be provided.

4.4. Assessment methods

This section summarizes methods for assessing RF exposure from emissions produced by the EUT in the range of 3 kHz to 10 MHz.

4.4.1. Basic restrictions

For a given EUT, RF exposure condition, and corresponding separation distance, the internal E-field levels induced within the body shall not exceed the applicable basic restrictions.

Measurement of the internal E-field within a representative tissue-equivalent phantom at the corresponding separation distance is the preferred assessment method. However, this may not always be feasible due to physical constraints, or the availability of suitable test equipment, tissue-equivalent phantom definitions and/or conservative assessment procedures.

The requirements for measurement-based assessments against the basic restrictions can be found in section 5.

4.4.2. Reference levels

This sub-section specifies requirements related to assessments based on the reference levels. Reference levels provide a means of assessing exposure based on incident field strengths instead of induced quantities. Many of the practical constraints associated with assessments against the basic restrictions are removed as the E- and H-fields produced by the EUT are evaluated in free space at the corresponding separation distance.

The NS-based reference levels should not be exceeded for a given EUT, RF exposure condition and corresponding separation distance. An assessment against the basic restrictions shall be performed for the EUT when the NS-based reference levels are exceeded.

Provided that suitable field probes and test equipment are available, measurement of the incident field strengths is the preferred method when assessing against the reference levels.

Refer to section 5.2 for the requirements for measurement-based assessments against the reference levels.

When incident field measurements are not feasible, either due to physical constraints or the availability of suitable field probes and test equipment, the field levels may instead be evaluated computationally. Computational assessment methods are described in RSS-102.NS.SIM.

4.4.3. Special considerations for whole-body exposure

The reference levels specified in RSS-102 are based on incident fields that are uniform over the volume of the human body. In the context of RF exposure from an EUT, whole-body exposure may occur for certain combinations of separation distance and source antenna dimensions, (e.g. when one or both are comparable to, or larger than, the human body). Although it is assumed that the whole body is being exposed, the incident fields may not be spatially uniform, and comparing the spatial maxima to the corresponding reference levels may be overly conservative.

Spatial averaging may be applied for whole-body exposure assessments against the reference levels in accordance with annex B 0, provided the following conditions are met:

a. an assessment against the basic restrictions is not feasible
b. when performing a measurement-based assessment, the field levels are consistently and measurably within the sensitivity range of the employed field probe at all spatial averaging locations and frequencies (probe sensitivity requirements are presented in section 5.3.5.1)
c. the maximum exposure ratio observed over all spatial averaging locations is not greater than twice the spatially averaged exposure ratio (procedures for evaluating exposure ratios in measurement-based assessments against the reference levels are presented in section 5.4)
d. the rationale and procedure are properly documented in the RF exposure technical brief

4.4.4. Special considerations for localized exposure

Localized exposure may also occur (e.g. when the separation distance and dimensions of the source antenna are small relative to the human body). Alternatively, the fields produced by the EUT may be largely confined to an area that is inaccessible to the entire body. In cases where the exposure occurs primarily within the limbs, comparing the highest observed field strength to the reference level may be overly conservative. This is particularly true for the H-field reference levels, as the conversion from incident H-field to internal E-field depends upon the size of the exposed region.

The relaxed H-field reference levels provided in Table may be applied for localized exposure assessments, provided the following conditions are met:

a. an assessment against the basic restrictions is not feasible
b. no spatial averaging is applied
c. the rationale and procedure are properly documented in the RF exposure technical brief

When employing the relaxed H-field reference levels for limb exposure, compliance shall also be demonstrated at the head/torso position without relaxation (i.e. a relaxation factor of 1.0 in accordance with table 2). Refer to Annex D for examples involving various device types.

Table 2: H-field reference level relaxation for local exposure

Exposure Region	Relaxation Factor	NS-based H-field (A/m RMS)
Head/torso	1.0	90
Leg	1.5	135
Arm	2.5	225
Hand/foot	5.0	450

5. Measurement-based assessments

This section provides the requirements related to measurement-based assessments of internal E-field and reference levels in the frequency range of 3 kHz to 10 MHz.

5.1. Internal E-field

ISED will provide the requirements for measurement-based assessments against the basic restriction for internal E-field in a future issue of RSS-102.NS.MEAS.

Until these requirements are available, applicants wishing to perform a measurement-based assessment against the basic restriction for internal E-field shall submit a General Inquiry form to ISED proposing an accurate and conservative approach for doing so.

5.2. Measurement-based assessments against the reference levels

The following sections provide the requirements related to measurement-based NS assessments against the reference levels in the frequency range of 3 kHz to 10 MHz. The test set-up employed for NS measurements in this band is similar to that employed for SAR measurements from 100 kHz to 4 MHz as outlined in RSS-102.SAR.MEAS due to the overlap in the applicable frequency range. Consequently, both NS- and SAR-related requirements are included in the following sections.

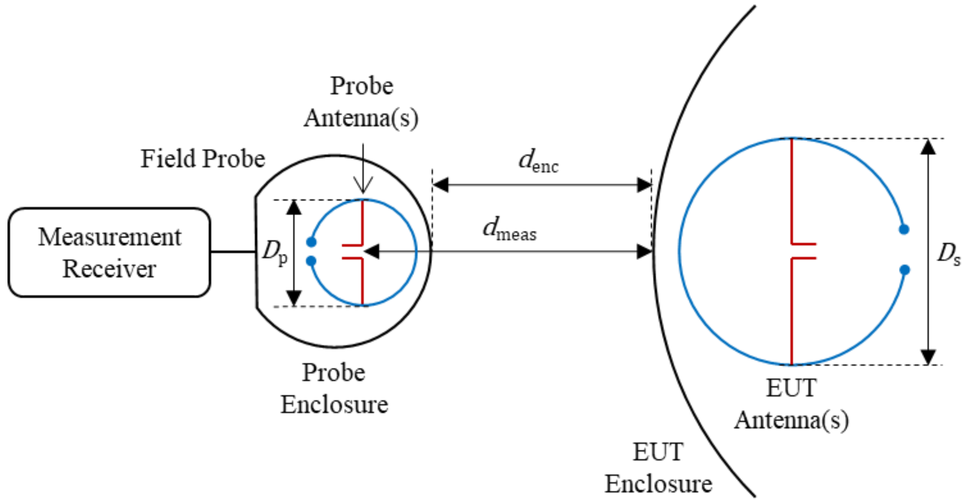
5.3. Test set-up

This section specifies the requirements for the test set-up.

5.3.1. Overview

Figure 1 illustrates a typical test set-up for performing incident-field measurements. The field probe used to conduct the measurements primarily consists of one or more probe antennas and a measurement receiver. Fields generated by the EUT excite a response in the probe antenna(s), which is processed by the measurement receiver and converted to an estimate of the desired exposure metric. In many cases, the probe antenna(s) and measurement receiver are integrated into a single device, and may share the same enclosure. Alternatively, a measurement receiver may be used with a variety of detachable probe antennas. Regardless, the measurement receiver shall present a suitable impedance to each antenna, and be capable of accurately converting the detected quantity (i.e. voltage or current) to the measured field strength (i.e. E-field or H-field) over the full frequency range of the assessment.

Figure 1: Illustration of a typical incident-field measurement



The distance corresponding to a given field measurement, denoted by d_{meas} in figure 1, is defined as the distance separating the EUT enclosure and the measurement location associated with the probe antenna(s) (i.e. the precise location in space that corresponds to the field measurement). If this location is not indicated by the probe manufacturer, the geometric centre of the probe antenna(s) or the probe enclosure may be used.

The enclosure distance, denoted by d_{enc} in figure 1, is the distance between the EUT and the nearest surface of the field probe enclosure.

In contrast, the separation distance, d_{sep}, is the minimum distance between the EUT and the nearest surface of the exposure region (i.e. the region over which RF exposure is to be evaluated). It is based on the RF exposure condition and limit under consideration. Ideally, incident field measurements would be performed at the corresponding separation distance (i.e. $d_{\text{meas}} = d_{\text{sep}}$). However, this may not be feasible in all cases due to spatial averaging effects (see section 5.3.6) and physical constraints. In such cases, a computational assessment in accordance with RSS.102.NS.SIM (or RSS.102.SAR.SIM currently in development) for NS or SAR, respectively, may be performed. Alternatively, curve-fitting techniques may be used to estimate the field value(s) at d_{sep} based on measurements taken at larger distances, provided an acceptable estimation error can be demonstrated, which requires submitting a General Inquiry form to ISED.

The shortest distance separating the probe and EUT antennas, denoted by d_{meas} in figure 1, is proportional to the probe antenna size requirements outlined in section 5.3.6.

5.3.2. Environment

When feasible, the assessment shall be performed in a controlled laboratory environment. The test set-up shall be kept well clear of metal objects or surfaces that can influence the assessment results. Tables and mounting apparatus for the measurement probes shall be RF transparent and their construction shall be free of metallic materials. The volume and shape of the electromagnetic field (as influenced by EUT output power and radiator size) shall be taken into consideration using best engineering practices to determine the appropriate clearance required to minimize the influence of metallic materials in the vicinity of the EUT.

In addition, the environment should be free of ambient signals within the frequency and sensitivity ranges of the field probe(s). If necessary, these signals may be measured and removed from the results, provided this is clearly documented in the RF exposure technical brief.

If the nature of the EUT is such that laboratory measurements are not feasible or practical (e.g. for an electronic article surveillance system) the assessment shall be performed *in situ* on at least three representative installations.

5.3.3. Frequency-domain vs. time-domain assessments

Measurement receivers can operate primarily in the frequency domain (e.g. spectrum analysis) or the time-domain (e.g. an oscilloscope). Frequency-domain assessments are less complex for SAR since reference levels are frequency dependant; however, frequency-domain assessments may not always be appropriate.

If the EUT emissions consist of unmodulated carriers (e.g. periodic sinewaves, pulse trains, etc) a frequency-domain assessment may be performed. This may be extended to emissions consisting of narrowband-modulated carriers, provided the resolution bandwidth (RBW) employed at each measurement frequency exceeds the occupied bandwidth (OBW) of the emission at that frequency. In the context of this document, modulation is classified as narrowband if the OBW is less than 1% of the carrier frequency. At a given frequency, measurement receivers operating primarily in the frequency domain shall employ an RBW in the range of 1% to 10% of the carrier frequency. In addition, they shall be capable of performing statistical functions such as mean and max-hold at each frequency, and shall be configured to use a peak detector to display RMS equivalent levels.

For all other EUT emissions (e.g. aperiodic or broadband-modulated) a time-domain assessment shall be performed. Measurement receivers operating primarily in the time-domain shall sample the field measurement signal(s) at a rate that is sufficiently high to prevent aliasing and fold-over effects. That is the sampling frequency or frequencies shall be higher than twice the highest frequency associated with the assessment (e.g. ≥ 20 MHz).

5.3.4. Assessment frequency range

The assessment shall consider the full frequency range of the corresponding exposure limit:

- 3 kHz to 10 MHz for the NS-based E- and H-field reference levels
- 100 kHz to 10 MHz for the SAR-based H-field reference level
- 1.10-10 MHz or 1.29-10 MHz for the SAR-based E-field reference level in uncontrolled or controlled environments, respectively

For EUT emissions meeting the requirements for a frequency-domain assessment outlined in section 5.3.3, multiple equipment set-ups may be employed to cover the full frequency range of a given exposure limit. This shall be noted in the RF exposure technical brief.

A reduced frequency range may be permitted for a given assessment, provided the EUT does not produce:

a. frequency components with emissions that are less than 20 dB below the maximum level identified over the frequency range of 3 kHz to 10 MHz or
b. emissions exceeding the probe sensitivity levels specified in 5.3.5.1 outside of this range

This shall be demonstrated via preliminary measurements using either a spectrum analyser or with a measurement receiver with a field probe that accommodates the full frequency range of the exposure limit under consideration, and meets the requirements outlined in sections 5.3.5.1 to 5.3.5.3 and 5.3.6.1. The resulting spectrum plot(s) shall be included in the RF exposure technical brief.

5.3.5. Probe requirements

This section specifies the applicable requirements for the probe.

Calibration data from an accredited calibration laboratory for the following sub-sections shall be provided in the RF exposure technical brief.

5.3.5.1. Probe sensitivity

The field probe(s) shall meet the following sensitivity requirements over the frequency range of the assessment:

- ≤ 1 V/m for E-field measurements

- ≤ 1 A/m for H-field measurements against the NS-based reference level
- $\leq 0.1/f_{\mathrm{MHz}}$ A/m for H-field measurements against the SAR-based reference level, where f_{MHz} is the measurement frequency in MHz

5.3.5.2. Probe level response

The field probe shall provide for an amplitude flatness of 1 dB or less over the entire frequency range of the assessment. Frequency-dependant amplitude weighting factors shall not be applied to the measurement results.

5.3.5.3. Probe linear range and linearity error

The field probe shall provide a linear range extending from at least -10 dB to +5 dB relative to the reference level associated with the assessment, and with a linearity error within ±0.5 dB.

5.3.6. Probe antenna requirements

This section specifies the applicable requirements for the antenna inside the field probe.

Most RF exposure assessments below 10 MHz are performed in the reactive near-field region of the EUT antenna(s). Spatial variations in the magnitude and polarization of the E- and H-fields can be significant in this region, and, as a result, care must be taken when selecting a suitable probe antenna. In addition to the requirements outlined in the following sections, field probes used to perform assessments within the reactive near-field region shall employ antennas that are designed and intended for near-field measurements.

5.3.6.1. Antenna size

Due to the finite size of the probe antenna(s), all field measurements will be subject to some degree of spatial averaging. For a loop antenna, the measurement location may be defined as the geometric centre of the loop, but the result will be a function of the average H-field passing through the loop aperture. A similar E-field averaging effect occurs in wire antennas.

The probe antenna shall be sufficiently small to ensure that the spatial peak of a given field component can be accurately measured. Referring to quantities illustrated in figure 1, the following condition shall be maintained to ensure this:

$$d_{\mathrm{meas}} \geq 1.7 D_{\mathrm{p}} \qquad (1)$$

If the maximum linear dimension of the probe antenna (D_{p}) is unknown, the maximum enclosure dimension shall be used. This requirement may be waived if one of following conditions is met:

a. $D_{\mathrm{p}} \leq 0.1D_{\mathrm{s}}$, where D_{s} is the maximum linear dimension of the largest active EUT antenna (the maximum dimension of the EUT enclosure shall not be used)
b. The nearest metallic surface (excluding the source antenna and accompanying electronics) is further than $1.7D_{\mathrm{p}}$ from the field measurement point (e.g. geometric centre of the probe antenna(s))

Example: The smallest antenna of a given EUT has a maximum dimension of 40 mm. This would correspond to the length of a dipole antenna, or the diameter of a circular loop antenna. The maximum dimension of the probe antenna is 12 mm. As a result, incident field measurements may only be performed at distances of at least 20 mm ($d_{\mathrm{meas}} \geq 20$ mm).

5.3.6.2. Isotropy

The reference levels are defined in terms of the vector magnitude of the incident field. Consequently, field measurements shall be performed for three orthogonal axes, defined as x, y and z for convenience, to enable calculation of the vector magnitude.

For EUT emissions requiring a time-domain assessment in accordance with section 5.3.3, the x, y and z components are recommended to be detected simultaneously by the measurement receiver. This should be achieved using a three-axis isotropic probe with a deviation from isotropy of 1 dB or less.

When performing measurements within the reactive near-field region, the individual elements of a three-axis probe antenna should share the same measurement centres (e.g. a three-axis H-field probe consisting of three concentric loops). If the maximum distance separating the measurement locations of any two elements exceeds $D_{\mathrm{p}}/20$, where D_{p} is the maximum dimension of the probe antenna, the probe antenna shall not be considered 'isotropic' in the reactive near-field region.

For EUT emissions meeting the requirements for a frequency-domain assessment in accordance with section 5.3.3, each field component may be measured sequentially, provided the corresponding antenna positioning requirements in section 5.3.6.3 are met.

5.3.6.3. Antenna positioning

The positioning apparatus for the field probe shall enable movement and orientation of the probe antenna(s) such that the maximum field levels produced by the EUT can be accurately and repeatably measured at the corresponding separation distance (assuming this is feasible based on the size of the probe antennas). This requires aligning the measurement centre(s) of the probe antenna(s) with the location(s) of maximum exposure on the evaluation surface. The measurement setup and positioning apparatus shall enable scanning of the measurement centre(s) of the probe antenna(s) on the evaluation surface, in any direction relative to the geometric centre of the EUT, without obstruction.

Example: When evaluating a table top device, the probe antenna enclosure should not rest on, or be obstructed by, the table or surface upon which the EUT rests, or any other surface at the same height, as this can unduly prohibit vertical scanning of the measurement centre(s) of the probe antenna(s) at or below the height of the geometric centre of the EUT.

When performing sequential measurements of the x, y and z field components to determine the vector magnitude of the field in a frequency-domain assessment (see section 5.3.6.2), the positioning apparatus shall enable rotation of the probe antenna such that each field component can be accurately and repeatably measured at the same location on the evaluation surface. The results obtained via sequential measurements shall be equivalent to those obtained using a three-axis isotropic probe antenna with a deviation from isotropy of 1 dB or less. If the measurements are performed within the reactive near-field region, the positioning apparatus shall be capable of repeatably orienting the probe antenna(s) such that the maximum distance between any two field component measurements does not exceed $D_{\mathrm{p}}/20$.

5.4. Measurement procedure

This section specifies the requirements related to the measurement procedure for measurement-based assessments against the reference levels in the frequency range of 3 kHz to 10 MHz.

5.4.1. General requirements

Measurements shall be performed in accordance with the following the requirements for both the E- and H-field levels; calculations to derive one from the other will not be accepted.

For a given exposure condition, the user-accessible space surrounding the EUT shall be considered at the corresponding separation distance. Whenever possible, all transmitters capable of simultaneous operation shall be active throughout the assessment. Otherwise, the exposure contributions of each transmitter, or a combination thereof, shall be evaluated and combined in accordance with section 5.5. Photographs depicting the full test set-up, particularly for the configurations yielding highest exposure, shall be provided.

Preliminary scanning measurements should be performed to determine the location(s) of maximum exposure (i.e. where the E- and H-field levels are highest) on the evaluation surfaces associated with each user-accessible side of the EUT. At least one worst-case E- and H-field measurement shall be performed for each user-accessible side of the EUT.

If the EUT employs fundamental, carrier or pulse repetition frequencies that can vary over time, the assessment shall capture the worst-case exposure arising from all possible combinations of frequency and excitation level.

5.4.2. Frequency-domain assessment

This sub-section applies to frequency-domain assessments.

5.4.2.1. General requirements for frequency-domain assessments

In accordance with section 5.3.3, the assessment may be performed in the frequency-domain if the transmit waveforms consist of unmodulated or narrowband-modulated periodic carriers. It is assumed that the measurement receiver computes and/or displays the RMS equivalent level (using a peak detector) associated with each frequency component; otherwise, the values shall be scaled appropriately.

The vector magnitude of the RMS E-field level, denoted by $E(f)$, can be expressed as:

$$E(f) = \sqrt{[E_x(f)]^2 + [E_y(f)]^2 + [E_z(f)]^2} \quad (2)$$

where $E_x(f)$, $E_y(f)$ and $E_z(f)$ are the x, y and z components of the RMS equivalent E-field level (using a peak detector), respectively. Similarly, for the H-field:

$$H(f) = \sqrt{[H_x(f)]^2 + [H_y(f)]^2 + [H_z(f)]^2} \quad (3)$$

Note: as these are the RMS levels of a largely periodic signal, the components need not be measured simultaneously (i.e. single-axis measurements may be performed).

At a given frequency, the RBW of the measurement receiver shall be in the range of 1% to 10% of that carrier frequency.

5.4.2.2. NS-based reference levels

The NS-based reference levels apply to the maximum instantaneous RMS E- and H-fields, respectively. When performing an assessment in the frequency domain, the maximum instantaneous RMS value can be conservatively evaluated by summing the maximum RMS levels associated with each frequency component of the EUT emission. For this, the measurement receiver shall record/display the spectrum in a max-hold configuration. The measurement time interval shall allow for the spectrum levels to converge, and shall not be less than 1 second.

Once the spectrum levels have converged, the RMS contributions can be combined. To limit the effects of measurement noise on the assessment results, the frequency components considered in the summation may be limited to those for which the field levels exceed the corresponding sensitivity levels specified in section 5.3.5.1. Thus, the NS-based exposure ratio associated with the incident E-field, denoted as $ER_{\mathrm{NS-ERL}}$, can be computed as:

$$ER_{\mathrm{NS-ERL}} = \frac{1}{E_{\mathrm{NS-RL}}} \sum_{m=1}^{M} E(f_m) \tag{4}$$

where:

- M is the total number of frequency components for which the field levels are within the probe sensitivity range
- f_m is the frequency of the m-th component
- $E_{\mathrm{NS-RL}}$ is the NS-based reference level for the incident E-field

Similarly, for the H-field:

$$ER_{\mathrm{NS-HRL}} = \frac{1}{H_{\mathrm{NS-RL}}} \sum_{m=1}^{M} H(f_m) \tag{5}$$

5.4.3. Time-domain assessment

This section applies to time-domain assessments.

5.4.3.1. General requirements for time-domain assessments

When a time-domain assessment is performed, the x, y and z components of the E- and H-fields shall be measured simultaneously. The measurement receiver shall directly sample the associated EMF signals, with all subsequent processing and detection steps being performed computationally. In other words, the measurement receiver shall output and/or display the instantaneous field values instead of the envelope or the RMS level(s) associated with a given frequency component. The vector magnitude of the instantaneous E-field, denoted by $E(t)$, can be expressed as:

$$E(t) = \sqrt{[E_x(t)]^2 + [E_y(t)]^2 + [E_z(t)]^2} \qquad (6)$$

where $E_x(t)$, $E_y(t)$ and $E_z(t)$ are the x, y and z components of the instantaneous E-field, respectively. Similarly, for the H-field:

$$H(t) = \sqrt{[H_x(t)]^2 + [H_y(t)]^2 + [H_z(t)]^2} \qquad (7)$$

5.4.3.2. NS-based reference levels

The NS-based reference levels apply to the maximum instantaneous RMS E- and H-fields, respectively. For convenience, the analytical steps will be demonstrated for the E-field. The same steps shall be applied to the H-field.

The instantaneous RMS E-field, $E_{\text{rms}}(t)$ can be expressed as:

$$E_{\text{rms}}(t) = \sqrt{\frac{1}{T}\int_{t-T/2}^{t+T/2} [E(\tau)]^2 \, d\tau} \qquad (8)$$

where T corresponds to the inverse of the highest frequency associated with the assessment and τ represents the time variable in the integrand (it is only introduced to avoid ambiguity in the equation).

Note: a conservative value of $T = 0.1$ µs may be used, or $E_{\text{rms}}(t)$ may be set equal to $E(t)$.

The maximum instantaneous RMS value of the E-field, E_{max}, shall be the maximum value of $E_{\text{rms}}(t)$ observed over the full measurement time interval, which, in turn, shall be sufficiently long to ensure that E_{max} has converged. This time interval shall not be less than 1 second.

Based on the value of E_{max} and the corresponding reference level, $E_{\text{NS-RL}}$, the exposure ratio contribution associated with this measurement can be computed as:

$$ER_{\text{NS-ERL}} = \frac{E_{\text{max}}}{E_{\text{NS-RL}}} \qquad (9)$$

where $ER_{\text{NS-ERL}}$ is the NS-based exposure ratio contribution from the incident E-field. Similarly, for the H-field we have:

$$ER_{\text{NS-HRL}} = \frac{H_{\text{max}}}{H_{\text{NS-RL}}} \qquad (10)$$

5.5. Total exposure

Compliance with the limits to prevent NS effects is demonstrated if the worst-case total exposure ratio (TER) corresponding to the effect is less than or equal to 1. NS- and SAR-based TERs are evaluated separately. Refer to section 8 of RSS-102 for details.

6. RF exposure technical brief

The RF exposure technical brief shall include all information required to reproduce the measurement results, including information related to the test configurations, methods and equipment. Annex A provides a comprehensive list of the required information.

If the EUT produces emissions above 10 MHz, additional assessments are required to fully demonstrate compliance. In this case, the RF exposure technical brief shall accommodate any additional reporting requirements identified in the RSS-102 series of standards.

Annex A. Summary of required information for the RF exposure technical brief (normative)

This annex provides a comprehensive summary of the information that must be included in the radio frequency (RF) exposure technical brief to demonstrate compliance with this RSS-102.NS.MEAS.

A.1. General information

Table A1 summarizes the general information to be included in the RF exposure technical brief.

Table A1: General information to be included in the RF exposure technical brief

Item description	Related section(s)
Test laboratory information, including Innovation, Science and Economic Development Canada (ISED) recognition and accreditation, as well as the evaluation dates	4
Equipment under test (EUT) use-cases and key RF exposure conditions	4.1
List of the nerve stimulation (NS)- and specific absorption rate (SAR)-based separation distances associated with each individual assessment, with sufficient rationale as required	4.2
Description of the nature, intended purpose and theory of operation of the equipment under test (EUT), including information related to certification (i.e. ISED Certification Number, HVIN, PMN, HMN etc.)	4.3.1
Description of each antenna within the EUT, including the number of elements, element type relevant, dimensions, etc.	4.3.2
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.	4.3.3
Description of EUT behaviour in each operating state, and the triggering conditions and timings for state transitions	4.3.4
Description of the conducted power of excitation level applied to each antenna based on the applicable use-cases and operating states	4.3.5
List of the methods used for each assessment against the NS-based limits, with sufficient rationale as required	4.4

Summary of the exposure ratio results obtained for each assessment, along with the worst-case NS-based total exposure ratios (TERs)	5.5

A.2. Measurement-based assessments against the reference levels

Table A2 summarizes the information to be included in the radio frequency (RF) exposure technical brief for measurement-based assessments against the reference levels.

Table A2:Information to be included in the RF exposure technical brief regarding measurement-based assessments against the reference levels

Item description	**Related section(s)**
Description of the test set-up, including: field probe(s) and other test equipment, test environment(s) and physical configuration(s) of the EUT	5.3.1, 5.3.2
List of EUT emissions under consideration, and whether a frequency-domain or time-domain assessment is applicable, with rationale	5.3.3
Assessment frequency range(s), with additional details and sufficient rationale for frequency range reduction(s) or the use of multiple equipment set-ups to cover the full range(s)	5.3.4
Field probe specifications, including: frequency range, calibration certificates, sensitivity, level response, linear range and linearity error, antenna size (D_{p}) and isotropy	5.3.5
Size(s) of the relevant EUT antenna(s) (i.e. D_{s} values) along with the corresponding values of d_{ant} and, if necessary, d_{enc} and/or d_{sep}, to demonstrate that the measurements have been performed in accordance with Equation (1) (i.e. the antenna size requirements have been met)	5.3.6.1
Description and relevant specifications of the positioning apparatus for the field probe	5.3.6.3
Description of the scanning procedure to find the locations of maximum exposure at the corresponding separation distance (i.e. on the evaluation surface) for each field component and user-accessible side of the EUT	5.4.1

Detailed description of the steps taken to convert the measured field levels to the corresponding exposure ratio(s) (i.e. $ER_{\mathrm{NS-ERL}}$ $ER_{\mathrm{NS-HRL}}$ and/or $ER_{\mathrm{SAR-RL}}$)	5.4.2 and/or 5.4.3
Photographs depicting the full test set-up, particularly for the configurations yielding highest exposure	5.4
Time-domain plots demonstrating illustrating the required time for the WPT source to shut down upon test load removal	C.2.3

Annex B. Spatial averaging for whole-body exposure assessments (normative)

This annex provides the requirements related to the application of spatial averaging to whole-body exposure assessments against the reference levels.

B.1. General

When applying spatial averaging, each individual measurement shall be performed in accordance with the requirements in section 5.2.

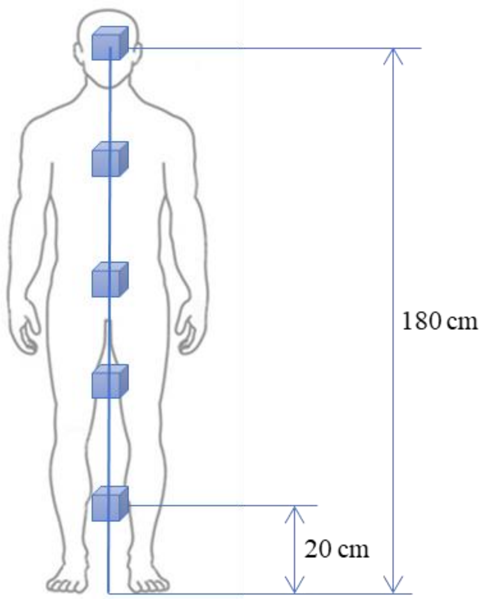
If the field levels associated with a particular source of emissions are not within the sensitivity range of the field probe at every spatial averaging location and frequency, spatial averaging shall not be applied for that source (see section 5.3.5.1 for probe sensitivity requirements).

Spatial averaging for whole-body exposure assessments (for both E-field and H-field against nerve stimulation (NS) and specific absorption rate (SAR) reference levels) shall only be permitted when the arithmetic mean of the measurements is greater than or equal to half the value of the maximum observed single point measurement as per section 5.4. Spatial averaging is not permitted if the arithmetic mean of the measurements is less than half the value of the maximum observed single point measurement.

B.2. E-field

Spatial averaging of E-field exposure is performed over the vertical extent of the human body. It is conservatively assumed that this extent is 180 cm, representing a tall adult. The full extent shall first be scanned to identify the location of maximum exposure. Additional measurements shall be performed at a minimum of five discrete heights, as illustrated in figure B1. This would provide for 40 cm spacing between sample points. If one of these points coincides with the location of maximum exposure, it shall only be included once in the spatial averaging calculation.

Figure B1: Illustration of minimum requirements for discrete sampling when performing E-field spatial averaging measurements



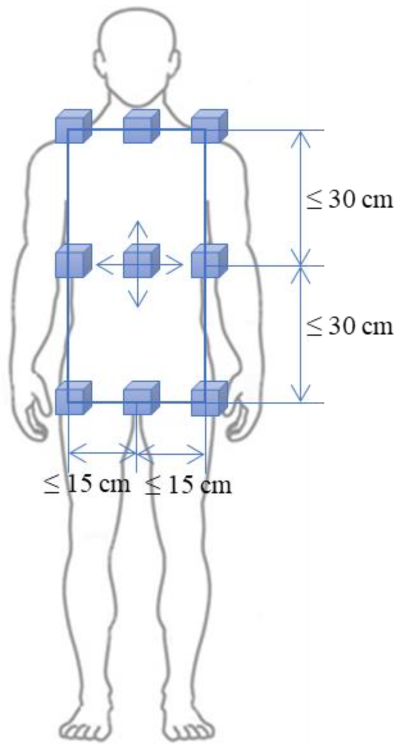
For assessments against the NS-based reference levels, $ER_{\mathrm{NS-ERL}}$ shall be evaluated at each measurement location in accordance with section 5.4. The arithmetic mean of the results shall be taken as the spatially-averaged NS-based exposure ratio contribution from the assessment. Instruments capable of performing automated E-field measurements and computing the spatially-averaged result may be used, provided the probe moves uniformly through the fields at a rate that yields reliable and conservative results given the time-varying nature of the emissions.

B.3. H-field

In the case of H-field spatial averaging, it is assumed that the source is a loop or coil antenna. Averaging is performed over a planar area, which is parallel to the plane of the antenna and positioned such that the worst-case exposure is captured. The dimensions of the averaging area should match those of the source antenna; however, at no point shall the height and width of the area exceed 60 cm and 30 cm, respectively, as these dimensions approximate the average size of a human torso.

Measurements shall be performed on a nine-point grid as depicted in figure B2. The locations of the outer points are uniformly spaced based on the dimensions of the source antenna or human torso. The central measurement shall be taken at the location of maximum exposure within the averaging area, unless this coincides with one of the measurement locations, in which case the central measurement shall be performed at the geometric centre of the averaging area.

Figure B2: Illustration of discrete sampling requirements when performing H-field spatial averaging



If the source antenna dimensions are less than 60 cm high and 30 cm wide, the spatial averaging area will vary. The outer points of the measurement grid shall not exceed the maximum dimensions of the source antenna. If the dimensions of the source antenna are less than three times those of the associated probe antenna(s), the number of grid points shall be reduced to five, with the middle measurement points of the outer perimeter being omitted and the central measurement being performed in the geometric centre of the grid.

For source antennas with dimensions exceeding 60 cm high and 30 cm wide, spatial averaging shall be performed over grids for which the corner measurements are maximized. This may require multiple grid locations over the area of the source aperture antenna. The maximum H-field is often near the edge of the antenna aperture, thus coinciding with the perimeter of the grid. In this case, the central measurement shall be performed at the geometric centre of the grid.

For NS-based assessments, $ER_{\mathrm{NS-HRL}}$ values shall be evaluated at each measurement location in accordance with section 5.4. The arithmetic mean of the results shall be taken as the spatially-averaged NS-based exposure ratio contribution from the assessment.

Annex C. Additional requirements for wireless power transfer implementations (normative)

This annex provides additional requirements specific to wireless power transfer (WPT) implementations. Note that SAR-related requirements are included due to the overlap in the operating frequency range.

C.1. General

The equipment under test (EUT) associated with a WPT implementation is assumed to consist of one or more WPT sources and one or more WPT clients. If a WPT source is designed to work with a variety of WPT clients (e.g. a table top charger) and does not qualify for the reduced computational assessment procedure defined in section B.1 of annex B in RSS-102.NS.SIM, *Simulation Procedure for Assessing Nerve Stimulation (NS) Compliance in Accordance with RSS-102* the EUT shall include one or more representative WPT clients, such that the worst-case radiofrequency (RF) exposure is captured. In this case, rationale for the chosen WPT client(s) shall be provided in the RF exposure technical brief.

In addition to the information requested in section 4.3, the operational description of a WPT implementation shall include the following:

a. The mechanism of wireless coupling for the purpose of power transfer. Common examples include, but are not limited to: inductive, capacitive, magnetic field resonance and electric field resonance.

b. The power profile during operation. For each combination of WPT source and WPT client, this includes:
    i. the nominal and maximum transmit power of the WPT source
    ii. the relationship between transmit power and displacement of the WPT client, in any direction, from the position and orientation yielding optimal performance
    iii. the maximum displacement that can be tolerated in each direction before power transfer is interrupted and
    iv. the relationship between the transmitted power and the loading condition of the WPT client (e.g. battery charge level)

c. If applicable, the communication protocol between the WPT source(s) and WPT client(s) for the purpose of power transfer management shall be described.

d. For each relevant use-case in the context of RF exposure, the number of WPT sources and WPT clients involved shall be identified, along with the nature of user or bystander interaction with the system.

Note: Some devices can act as either a WPT source or a WPT client, depending on the use-case. For these devices, details for each mode of operation shall be provided.

C.2. Exposure conditions

This section provides requirements relating to exposure conditions from WPT implementations.

C.2.1. Overview

In accordance with sections 4.1 and 4.2, the key RF exposure conditions, along with the corresponding separation distances, shall be identified. For WPT implementations incorporating a single WPT source and WPT client, the exposure conditions can be broadly divided into two categories:

- exposure from the WPT system during power transfer
- direct exposure from the WPT source

Further requirements regarding these categories is provided in the following sections.

For systems incorporating multiple WPT clients and/or WPT sources, exposure conditions for all possible combinations of WPT sources and WPT clients shall be identified.

C.2.2. Exposure from the WPT system during power transfer

This exposure category can be described as follows: a WPT source is transferring power to a sufficiently aligned WPT client, while a user is nearby. Compliance shall be demonstrated for the worst-case combination of:

a. transmit power, assuming 100% duty cycle
b. displacement of the WPT client, in any direction where WPT is still activated, from the position and orientation yielding optimal WPT performance
c. user/bystander position at the corresponding separation distance

Compliance shall also be demonstrated when the WPT client is optimally positioned.

The separation distance(s) for assessments against the SAR and NS-based limits shall be determined in accordance with section 4.2. For consumer products such as table top charging pads, WPT-enabled portable devices, etc., assessments against the nerve stimulation (NS)-based limits shall be performed at touch position (0 cm), because the user will interact directly with one or more of the WPT devices involved. For the example of a charging pad, a user would deposit their device directly upon the pad, and may retrieve it at any point during the charging cycle.

C.2.3. Direct exposure from the WPT source

Depending on the implementation, it may be possible for a user to be directly exposed to RF energy produced by a WPT source. This may occur as one or more WPT clients move in and out of the coupling region of the WPT source over time. In the absence of a sufficiently coupled WPT client, the antenna(s) or coupling element(s) of a WPT source may continue to be energized in an effort to ‘search’ for a viable WPT client. This may be done at a reduced duty cycle, reduced power level, or both. Compliance shall be assessed when a user is in the worst-case position (e.g. at the minimum separation distance in front the coupling element(s) of the WPT source).

Direct exposure from a WPT source may be significant immediately following the sudden removal of a WPT client during power transfer. Depending on the time required for the WPT source to recognize the removal of the WPT client and power down, it is possible for the user to be exposed to the fields from the fully energized WPT source, representing a worst-case exposure scenario for NS (instantaneous exposure). This timing shall be provided in the RF exposure technical brief, in accordance with section 4.3.4. Compliance shall be assessed when the user is in the worst-case position (e.g. at the minimum separation distance in front the coupling element(s) of the WPT source) unless the WPT source is able to power down in less than 1 second, or it can be demonstrated that alternative measures have been taken to prevent this exposure scenario. Time-domain test plots demonstrating that the WPT source shuts down within 1 second of the test load being removed shall be included in the RF exposure technical brief.

For WPT implementations in which the user directly interacts with the devices involved, direct exposure from the WPT source shall be assessed at touch position (0 cm).

C.3. Assessments against the reference levels for electric vehicle WPT implementations

This section provides requirements for assessing electric vehicle (EV) WPT implementations.

C.3.1. Applicable implementations

The requirements provided in the following sections applies to EV WPT implementations meeting the following criteria:

- The WPT source subassembly is designed to be located in or on the ground, forming part of a ground assembly (GA).

- The WPT client subassembly is mounted on the bottom surface of the EV, forming part of a vehicle assembly (VA).

For all other EV WPT implementations, a General Inquiry form shall be submitted to ISED.

C.3.2. General requirements

For EV WPT implementations meeting the criteria of section C.3.1, compliance may be demonstrated by performing an assessment against the reference levels. These assessments shall be performed via measurements in accordance with section 5.2, or simulations using a validated computational model in accordance with RSS-102.NS.SIM. If the reference levels are exceeded, an assessment against the basic restrictions is required, and a General Inquiry form shall be submitted to ISED.

A complete assessment shall capture the NS-based exposure ratios under the worst-case combination of:

- System configuration (e.g. single or multiple GAs) and VAs, etc.)
- Wireless gap and horizontal misalignment between the GA(s) and VA(s)
- Charging state of the EV
- Exposure condition:
    - direct exposure from the GA(s) (i.e. no vehicle present) if applicable
    - exposure from the EV WPT system during charging (e.g. inside the vehicle, outside the vehicle, or reaching underneath the vehicle)

If the GA(s) produce emissions in the range of 3 kHz to 10 MHz when the vehicle is absent (e.g. in searching for a viable WPT client) direct exposure from the GA(s) shall be assessed. In this case, the GA(s) may be treated as floor-mounted and walked-over devices, and assessed in accordance with the relevant procedure in section D.2 of Annex D.

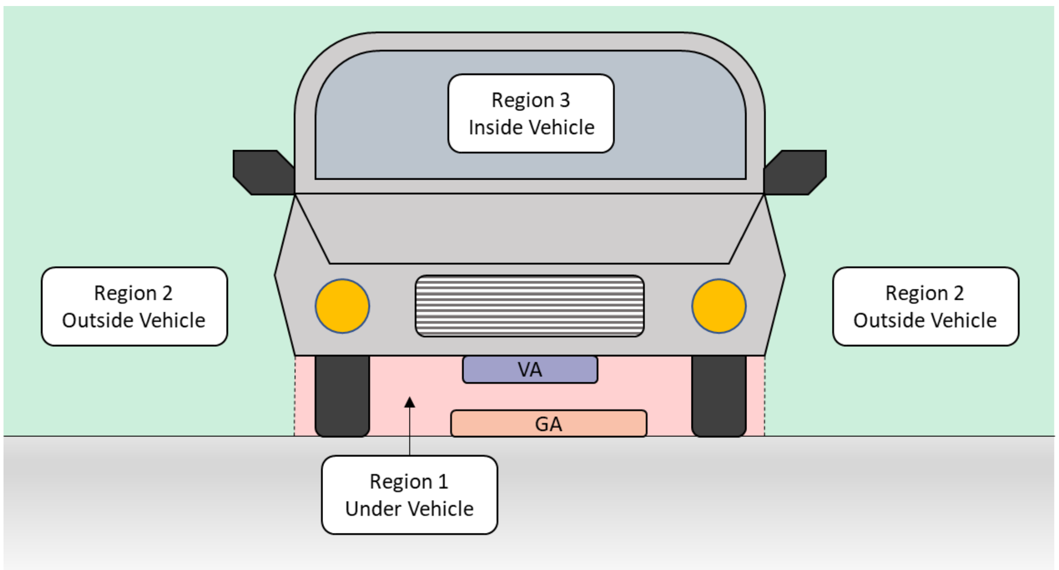
While the EV is being charged, consideration must be given to the fields surrounding the vehicle. These can be broadly divided into three distinct regions as illustrated in figure C-1:

- Region 1, Under the vehicle: The highest field levels are usually observed in this region, as this is where the GA(s) and VA(s) are mounted. This is also the least-accessible region during charging, and it is assumed that the most likely exposure scenario is a user or bystander reaching underneath the vehicle to retrieve or search for an object during the charging cycle.

- Region 2, Outside the vehicle: Users or bystanders can stand beside or lean against the vehicle at any point during the charging cycle. Due to the blocking provided by the chassis of the vehicle, in most cases it is expected that the highest fields would be observed near the gap between the ground and the bottom of the chassis.

- Region 3, Inside the vehicle: Users or bystanders can occupy any of the seats within the vehicle at any point during the charging cycle.

Figure C1: Illustration of an EV WPT implementation (front view)



C.3.3. Region 1, Under the vehicle

The NS-based reference levels should not be exceeded when an adult or child reaches underneath the vehicle at any point during the charging cycle. Otherwise, an assessment against the basic restriction shall be performed. The H-field relaxation factor for arm exposure may be used, provided the ground clearance of the EV is such that it is not realistic or practical for an adult or child to have their head underneath the vehicle.

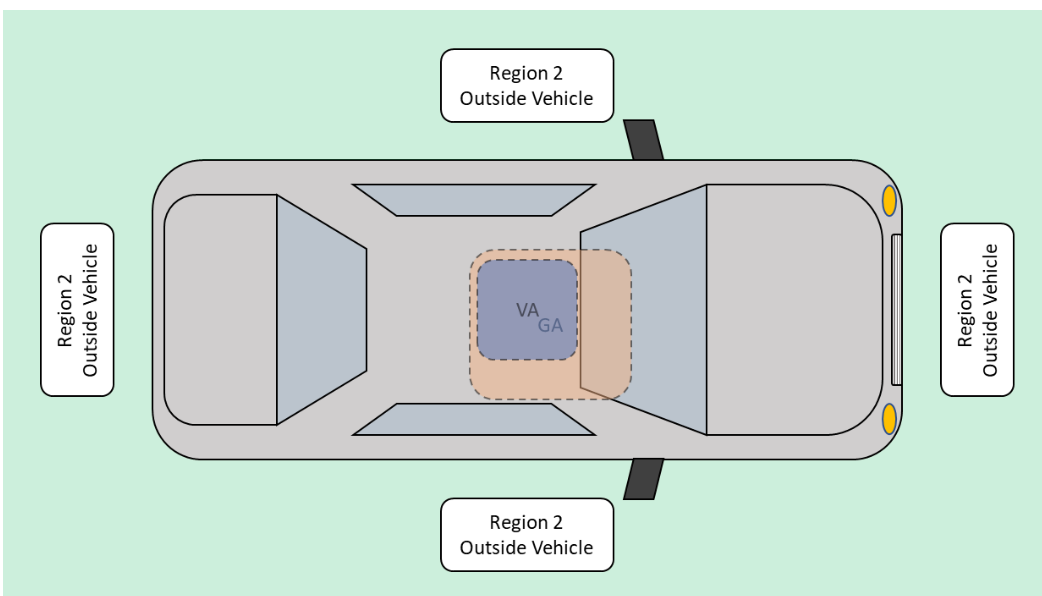
If sensors are used to detect the presence of living tissue or other foreign objects and reduce power accordingly, this function shall be described in the RF exposure technical brief. The coverage area of the sensor implementation shall be defined as the region within which the hand of a small child is consistently and reliably detected, and the appropriate safety measures are triggered. This shall be validated experimentally, taking into account any hysteresis effects associated with the triggering, as well as the operating conditions of the EV WPT system (e.g. system configuration, wireless gap, misalignment, loading conditions). The validation results shall be used to determine the worst-case exposure condition(s) associated with region 1. These conditions shall be noted in the RF exposure technical brief, along with the corresponding assessment results.

C.3.4. Region 2, Outside the vehicle

This region extends from the outer surface of the vehicle chassis, neglecting protrusions such as side mirrors, as illustrated in figure C1 and in figure C2. The NS-based reference levels should not be exceeded anywhere in region 2. Otherwise, an assessment against the basic restriction shall be performed. Relaxation factors shall not be applied for NS-based assessments in this region.

If the EV WPT system produces emissions above 100 kHz, including harmonics, an assessment against the specific absorption rate (SAR)-based reference levels shall be performed in region 2. As for NS, the SAR-based reference levels should not be exceeded anywhere in region 2; however, the relaxed SAR-based H-field reference level for leg exposure, shown in Table , may be applied below 85 cm from the ground. If the reference levels are exceeded, an assessment against the basic restrictions shall be performed.

Figure C2: Illustration of an EV WPT implementation (top view)



C.3.5. Region 3, Inside the vehicle

Inside the vehicle cabin, assessments shall be made against the NS-based reference levels and, if applicable, the SAR-based reference levels. These levels should not be exceeded anywhere within the cabin. Otherwise, an assessment against the basic restrictions shall be performed. The SAR-based assessment may focus on the driver and passenger seating areas. The following shall be considered in the application of H-field relaxation factors:

a. Exposure of the feet resting on the floor of the cabin: the H-field relaxation factors for hand/foot exposure may be applied up to a height of 10 cm from the floor of the cabin.

b. Exposure of the legs while seated: the H-field relaxation factors for leg exposure may be applied up to a height of 50 cm from the floor of the cabin.

c. Head and torso exposure while seated: this covers heights above 50 cm from the floor of the cabin, and H-field relaxation factors are not applicable.

Annex D. Additional requirements for various device types (normative)

This annex provides additional requirements for a number of common device types, with the exception of wireless power transfer (WPT) implementations, which are covered in Annex C. Note that specific absorption rate (SAR)-related requirements are included due to the overlap in the operating frequency range.

D.1. Floor-standing devices

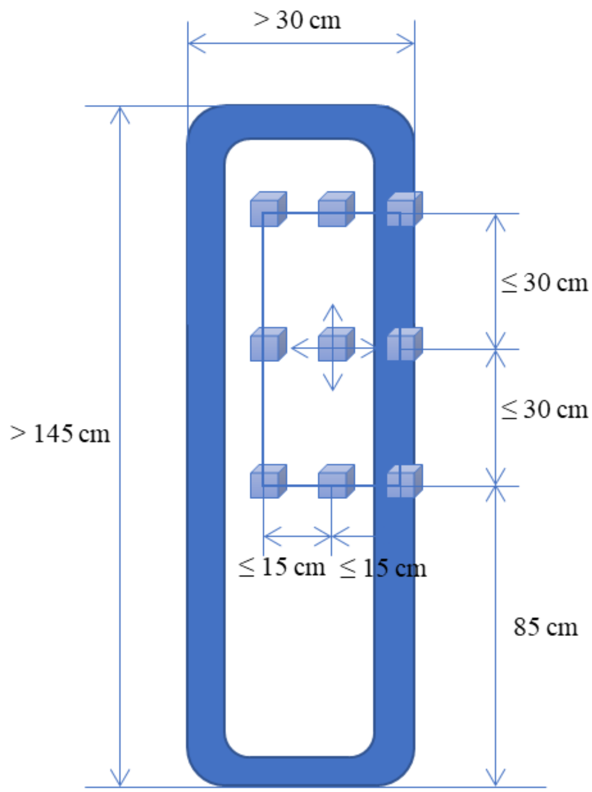
This section provides additional requirements for floor-standing devices, examples of which include:

- Electronic article surveillance (EAS) systems, which typically consist of antennas set on each side of an opening at the entrance or exit of a store. They are used to detect tags that pass through the area.
- Radiofrequency identification (RFID) turnstiles, which typically require that the user pass an RFID card over the turnstile to gain access to the entrance way.
- Walk-through devices, which are typically metal detectors that the human body would pass through.

D.1.1. Torso grid positioning for H-field spatial averaging in assessments against the reference levels

For floor-standing devices with antennas that are taller than 145 cm and wider than 30 cm, the torso grid shall be 85 cm above the floor and positioned such that the right or left edge of the grid is at the location of highest exposure. An example illustration of torso grid positioning is shown in figure D1.

Figure D1: Illustration of the torso grid positioning for H-field spatial averaging when the antenna(s) of a floor-standing equipment under test are taller than 145 cm and wider than 30 cm



For floor-standing devices with antennas that are smaller than the torso grid, or that are positioned such that they are lower than 85 cm and only cover a portion of the torso grid, the spatial averaging area shall remain above 85 cm, and averaging shall not be performed beyond the dimensions of the antenna(s).

D.2. Floor-mounted devices

This section provides additional requirements for floor-mounted devices, examples of which include:

- Floor-mounted and walked-over devices, such as timing devices used during races, where the runner moves over an antenna on the ground that reads an radiofrequency identification (RFID) device worn by the runner.

- Floor-mounted devices that are obstructed by an object (i.e. devices that are placed on the floor and are active while an object is over its surface). The exposure condition is to a human in the area beside the object.

Note: small floor-operated devices (i.e. any of the above devices) or simply a device that is placed on the floor and uses RFID to perform some action, may be treated as table top devices and assessed in accordance with section D.5.

D.2.1. Assessment locations

Exposure from any floor-mounted devices that can be walked over by the general public shall be assessed from 0 cm to 180 cm, along the axis yielding the worst-case results.

For floor-mounted devices that are obstructed by an object (i.e. members of the general public cannot walk over the device during operation) the assessment shall be performed without the obstructing object in place. This may require the use of test-mode software. Exposure shall be evaluated at a sufficient number of radials around the perimeter of the typical obstructing object to provide a minimum separation of 22.5° between each radial. At each radial, exposure shall be evaluated from 0 cm to 180 cm above the floor for non-metallic obstructions, and from 0 cm to the average exposure height for metallic obstructions. In the latter case, the average exposure height and corresponding rationale shall be provided in the RF exposure technical brief.

D.2.2. Spatial averaging

Spatial averaging shall not be applied when performing an assessment of a floor-mounted device.

D.2.3. Limb relaxation factors

In the case of floor-mounted and walked-over devices, the foot relaxation factors may be applied from 0 cm to 10 cm. The leg relaxation factors may be applied from 10 cm to 85 cm. Above 85 cm relaxation factors shall not be applied.

For floor-mounted devices that are obstructed by an object (i.e. members of the general public cannot walk over the device during operation) the leg relaxation factors may be applied at heights up to 85 cm. Above 85 cm, relaxation factors shall not be applied.

D.3. Hand-held devices

This section provides additional requirements for hand-held devices, examples of which include:

- Hand-held devices used to scan a human body, such as metal detector wands. These devices are used in close contact with the human body and the exposure condition is focused on the body being scanned and not as focused on the user of the equipment.

- Hand-held devices used to scan an object, such as hand-held radiofrequency identification (RFID) readers. These devices are typically used to scan objects instead of a human body, and so the main goal is to assess RF exposure in the extremities of the user (i.e. hand(s)).

D.3.1. Assessment locations

For hand-held devices used to scan the human body, the assessment shall be performed at a height of 130 cm. The assessment should be performed in all orientations surrounding the hand-held device. Alternatively, the hand-held device may be tested as a table top device on three orthogonal axes, following the procedure in section D.5.

For hand-held devices used to scan an object, the assessment shall be performed at a height of 100 cm. The assessment shall focus on the area where the hand of the user would be placed and at the corresponding separation distance. If the regions of maximum exposure are not accessible due to the construction of the device, a computational assessment may be performed. Alternatively, a measurement-based assessment may performed on a disassembled device, provided the behaviour of the transmitters are not significantly impacted by the disassembly. This shall be demonstrated in the radiofrequency (RF) exposure technical brief.

D.4. Wall-mounted devices

This section provides additional requirements for wall-mounted devices. In this frequency range, these typically devices used for RFID purposes (e.g. they are mounted on the wall close to a door and used to read an RFID card).

Wall-mounted devices may be assessed in accordance with the procedure provided for table top devices, found in section D.5, but at the separation distances associated with this device. RF exposure evaluations should only be necessary in the directions away from the wall, provided the construction of the wall ensures a much larger separation distance than those identified for the device as per section 4.2.

D.5. Table top devices

This section provides additional requirements for table top devices.

D.5.1. Test setup

Table top devices can be assessed directly against the reference levels.

If the device is permanently installed within a table top, the assessment shall be performed assuming the user is positioned for worst-case exposure (e.g. at the closest edge of the table relative to the device). Otherwise, the device shall be placed at the edge of a non-metallic table that is 80 cm high. Support equipment used to operate the device shall also be placed along the edge, with a minimum of 10 cm between each component.

The following shall be demonstrated:

a. The hands of the user are not over-exposed when interacting with the device during operation. As per section 4.2, the NS-based assessment shall be performed at touch position (0 cm), and the SAR-based assessment shall be performed at a conservative separation distance based on six-minute exposure for table top devices. For assessments against the H-field reference levels, the hand/foot relaxation factors may be applied.

b. The legs of the user are not over-exposed when positioned beneath the table top, if applicable. The minimum expected distance between the bottom surface of the table top and the legs may be applied during the assessment, provided the value and rationale for this distance is documented in the RF exposure technical brief. For assessments against the H-field reference levels, the leg relaxation factors may be applied.

c. The core or torso of the user is not over-exposed. The distance between the torso and the edge of the table shall be 0 cm for the nerve stimulation-based assessment. For the SAR-based assessment, a conservative distance shall be considered based on six-minute exposure in accordance with section 4.2. Relaxation factors shall not be applied.

Note: All three conditions may be satisfied by demonstrating compliance with the un-relaxed reference levels at touch position (0 cm) on all sides of the EUT.