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Guideline

Guidelines for the Measurement of Radio Frequency Fields at Frequencies From 3 kHz to 300 GHz

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Canada

Preface

This technical guideline, entitled GL-01, Issue 4, *Guidelines for the Measurement of Radio Frequency Fields at Frequencies From 3 kHz to 300 GHz*, replaces GL-01, Issue 3, published in March 2015. Issue 4 has been revised in its entirety to be in accordance with the latest version of Health Canada's Safety Code 6 (SC6) guidelines.

Listed below are the main changes:

- Section 3.1, Incorporating time division duplex (TDD) frame structures in simulations
- Section 3.2, Clarified site characterization procedures
- Section 3.2, Clarified assessment procedure for frequencies above 3GHz
- Section 4.4, Consideration for the use of the actual maximum power for simulations
- Section 4.5, Clarified radar transmitting sites procedures
- Annex C, Incorporating traffic load on cellular systems for field measurements
- Various editorial changes.

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

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This document uses the following abbreviations and acronyms:

AM – Amplitude modulation
BPR – Broadcasting Procedures and Rules
BS – Base station
CPC – Client Procedures Circulars
FM – Frequency modulation
FDD – Frequency division duplex
FTP – File transfer protocol
GL – Guidelines
IEEE – Institute of Electrical and Electronics Engineers
IEC – International Electrotechnical Commission
MIMO – multiple-input, multiple-output
MDS – Multipoint distribution services
NS – Nerve stimulation
PCS – Personal communications services
RF – Radio frequency
RMS – Root mean square
SC6 – Safety Code 6
SAR – Specific absorption rate
TDD – Time division duplex
TN – Technical note
UHF – Ultra high frequency
UE – Uncontrolled environment
VHF – Very high frequency

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1.0 Purpose

This guideline describes the measurement procedures for different types of radiocommunication and broadcasting installations when verifying compliance with the "uncontrolled environment" requirements (including limits, access control, etc.) as set out in Health Canada's *Limits of Human Exposure to Radiofrequency Electromagnetic Energy in the Frequency Range from 3 kHz to 300 GHz* – commonly known as Safety Code 6. These measurement procedures were developed in consultation with Health Canada.

This document is intended for people working in the radiocommunication and broadcasting industry with the assumption that the surveyor has a basic knowledge of electromagnetic field theory and practice, including an understanding of radio frequency (RF) safety. These procedures do not extend to measurements in the very low frequency band (below 3 kHz).

2.0 Introduction

As a condition of authorization, under Innovation, Science and Economic Development Canada's (hereinafter referred to as ISED or the Department) tower siting policy, entitled *Radiocommunication and Broadcasting Antenna Systems* (CPC-2-0-03), compliance with Safety Code 6 (SC6) is an ongoing obligation and includes the consideration of combined effects of nearby antenna installations within the local radio environment. To determine compliance of these radio installations, ISED has developed various tools, guidelines and documents.

At any time, antenna installation proponents and operators may be required, as directed by ISED, to demonstrate compliance with the uncontrolled environment (UE) limits which are specified in SC6 and, where necessary, implement corrective measures (as outlined in CPC-2-0-20 entitled *Radio Frequency (RF) Fields — Signs and Access Control*). In order to demonstrate compliance, detailed calculations, computer simulations, and/or site surveys (measurements) may be required. In addition, all antenna installation proponents and operators are required to facilitate ISED's access to sites to conduct compliance audits. Compliance with SC6, including the implementation of access control measures and signage, must be undertaken with the highest regard for ensuring the safety and protection of the general public.

It is the responsibility of all proponents and operators of antenna installations to ensure that all radiocommunication and broadcasting installations, including all guy-wires and associated anchor points, comply with the UE limits at **all** times. Site compliance is based on the maximum possible RF emissions for the **entire site**, including the combined effects of nearby installations within the local radio environment, not only the proponent's or operator's own installation. Each proponent and operator at a given site, including those utilizing licence-exempt equipment, are responsible for ensuring the site complies with SC6 requirements. As part of this shared responsibility, each proponent and operator is expected to openly share their system installation parameters and work cooperatively with the other proponents and operators to ensure accurate and consistent analysis.

This document (GL-01) is used by the Department to assess compliance with the SC6 limits. It covers the measurement procedures for broadcasting and radiocommunication antenna system installations, including microwave, land mobile, paging, cellular, radar installations, etc.

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Technical Note TN-261, entitled *Safety Code 6 (SC6) Radio Frequency Exposure Compliance Evaluation Template (Uncontrolled Environment Exposure Limits)*, is an evaluation tool used by the Department to quickly assess the RF exposure compliance for simple radiocommunication antenna sites using mathematical calculations.

The Department's publication Broadcasting Procedures and Rules BPR-1, entitled *General Rules*, specifies the broadcasting application requirements to demonstrate compliance with SC6. BPR-1 contains the description of the required analysis and alternatives depending on the RF exposure results submitted by the applicant.

As indicated above, the Department uses various tools for conducting SC6 compliance evaluation for radio communication and broadcasting sites. Applicants and operators may employ prediction methods or other computational modelling software that take into consideration the near-field and far-field regions of antennas. Any prediction model used to demonstrate compliance must be based on sound engineering practices and must take into consideration the applicable SC6 UE exposure limits when analyzing the impact of radiocommunication and broadcasting stations located within the local radio environment.

2.1 Measurement Equipment

The latest version of IEEE Std C95.3, *IEEE Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields With Respect to Human Exposure to Such Fields, 100 kHz-300 GHz*, or IEC 62232, *Determination of RF field strength and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure*, should be consulted when determining the type and specification of the measurement equipment to be used when performing RF exposure measurements.

2.2 Measurements

The procedures presented in this document are used to verify compliance with the UE limits as set out in SC6 for the following:

1. measurements of radiated electromagnetic (EM) fields;
2. measurements of re-radiated EM fields; and
3. measurements of induced and contact currents.

2.3 Near-Field and Far-Field Regions

The space around a radiating antenna can be divided essentially into two regions, the near-field region and the far-field region. For an antenna with a maximum overall dimension that is small compared to the wavelength (i.e. electrically small antennas), the near-field region is mostly reactive and the electric and magnetic field components store energy while producing little radiation. This stored energy is transferred periodically between the antenna and the near-field. The reactive near-field region extends from the antenna up to a distance "R."

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$$R = \frac{\lambda}{2\pi} \qquad \text{(eq. 2.1)}$$

where "λ" is the wavelength.

There is no general formula for estimation of the field strength in the near-field for small antennas. Exact calculations can be made only for well-defined sources, such as dipoles and monopoles.

For electrically large antennas, the near-field region consists of the reactive field extending to the distance obtained in equation 2.1, followed by a radiating region. In the radiating near-field, the field strength does not necessarily decrease steadily with distance away from the antenna, but may exhibit an oscillatory character. The criterion commonly used to define the distance from the source at which the far-field begins is that the phase of the fields from all points on the radiating antenna does not differ by more than λ/16 (22.5 degrees). The distance from the antenna corresponding to this criterion is:

$$R = \frac{2 \cdot D^2}{\lambda} \qquad \text{(eq. 2.2)}$$

where "D" is the largest dimension of the antenna (m) (usually taken as the length).

However, as indicated in the SC6 Technical Guide, a larger phase difference (> λ/16) is acceptable in estimating where the far-field zone begins for the purpose evaluating compliance with SC6 limits. This assumption will result in a shorter distance where the far-field zone begins and is acceptable to use for estimating the worst-case scenario. Therefore, a realistic practical distance from a large antenna (e.g. a parabolic reflector) where the far-field begins, which provides close agreement with experimental results, can be obtained using the following relationship:

$$R = 0.5\frac{D^2}{\lambda} \qquad \text{(eq. 2.3)}$$

In the far-field region, the electric (E) field and magnetic (H) field are orthogonal and are interrelated with each other by a constant, the free-space impedance (377Ω). Therefore, by measuring one field, we can derive the other. However, when measurements are conducted in the near-field, the electric (E) field and magnetic (H) field need to be assessed separately as they are not related by a simple mathematical expression.

Note: Far-field measurements are only valid when the measurements are performed in the far-field region of all radiating elements located at the site under study.

Further information on near-field and far-field regions can be found in the appendix of TN-261.

2.4 Radiocommunication Services

In general, the measurement locations for services operating below 48 MHz will typically be in the near-field, implying that the measurement of both the electric (E) fields and the magnetic (H) fields is required. For services operating above 48 MHz, as the wavelengths of the electromagnetic fields are relatively short and the dimensions of the antenna are relatively small, the measurement locations will

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usually be in the far-field region. As a result, measurements of only the electric (E) field or the magnetic (H) field will normally be sufficient to assess compliance. In addition to field measurements, induced current and contact current may also be required for services operating up to 110 MHz.

3.0 General Measurement Procedures for RF Exposure Compliance Assessments

As outlined in SC6, the basic restrictions shall not be exceeded. The basic restrictions are specified:

1. to prevent the occurrence of nerve stimulation (NS), which is defined in terms of internal "in tissue" electric field strength from 3 kHz to 10 MHz; and
2. to prevent the occurrence of thermal effects, which is defined in terms of specific absorption rate (SAR) from 100 kHz to 6 GHz as well as power density from 6 GHz to 300 GHz.

It is important to note that, in practice, direct measurement of internal electric fields (NS), SAR or absorbed power density is only feasible under laboratory conditions or through modelling and is very difficult to perform in a field environment. Therefore, reference levels, which are derived from the basic restrictions, are specified in SC6 in terms of external unperturbed electric and magnetic field strength, power density, as well as induced and contact currents to ensure compliance with the corresponding basic restrictions. These reference levels are quantities that can be assessed in the field either by means of measurements or calculations.

When verifying compliance with SC6 requirements, the reference levels (UE limits) shown in Annex A will be used. From 3 kHz to 10 MHz, the reference levels are based on nerve stimulation (NS) and/or specific absorption rate (SAR). Assessments against NS-based limits involve instantaneous measurements (defined in this document as 30 seconds), whereas assessments against SAR-based limits involve time averaged measurements for a period of 6 minutes. From 10 MHz to 6 GHz, the reference levels are based on SAR only and measurement are averaged over 6 minutes. Above 6 GHz, the reference limits are based on power density. From 6 GHz to 15 GHz measurements are averaged over 6 minutes. Above 15GHz, the reference period is frequency dependent.

Sections 3.1 – 3.4 provide general measurement procedures to determine compliance with SAR-based limits.

3.1 Overview of Radio Frequency Compliance Measurement Procedures

To assess SC6 compliance with respect to the UE limits (in areas accessible to the public) at a specific site with radiocommunication and/or broadcasting antenna system installations, the following steps should be followed.

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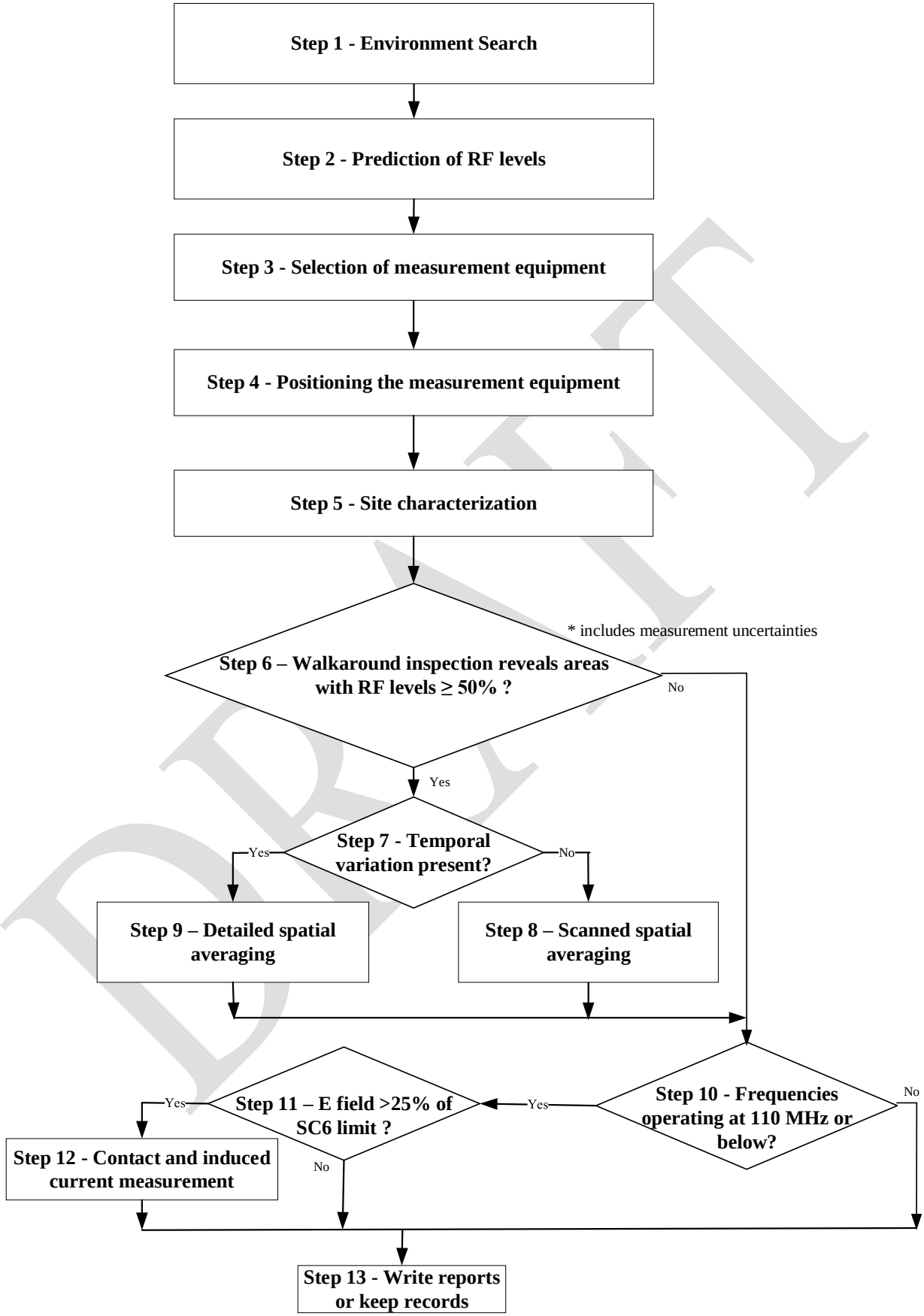
Step 1 - Environment Search
Step 2 - Prediction of RF levels
Step 3 - Selection of measurement equipment
Step 4 - Positioning the measurement equipment
Step 5 - Site characterization
Step 6 – Walkaround inspection reveals areas with RF levels ≥ 50% ?
* includes measurement uncertainties
No
Yes
Step 7 - Temporal variation present?
Yes
No
Step 9 – Detailed spatial averaging
Step 8 – Scanned spatial averaging
Step 10 - Frequencies operating at 110 MHz or below?
No
Yes
Step 11 – E field >25% of SC6 limit ?
Yes
No
Step 12 - Contact and induced current measurement
Step 13 - Write reports or keep records

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Step 1: Environment Search

Prior to on-site measurements, a radio environment search should be performed and data should be gathered for services located within the specified distance from the sites under consideration. In particular, the surveyor should gather all data for broadcasting stations within a radius of 1 km; and all data for terrestrial fixed transmitter stations in the land mobile, cellular, microwave, radar, radiolocation services, etc., within a radius of 100 metres.

Step 2: Prediction of RF levels

A prediction can be made to estimate RF levels for the site being surveyed and would be beneficial in identifying approximate locations with high RF to be measured. The prediction can be performed using TN-261 or other computational modelling software that take into consideration the near-field and far-field regions, as well as the applicable SC6 UE exposure limits.

When modelling time division duplex (TDD) systems using predictions, the maximum transmitted power (or EIRP) may be reduced by the duty cycle factor to account for the lower downlink resource allocation and better align with measurements. For example, a TDD site with 75% downlink and 25% uplink may be modelled with 75% of the maximum transmitted power for computation of the time averaged RF exposure values. However, in certain situations, the Department may require that the assessment be done using 100% of the maximum transmitted power. For FDD systems, 100% of the maximum transmitted power shall be used.

Note: When the maximum RF exposure, using worst case assumptions (maximum EIRP) in the theoretical analysis, is below 50% of the UE limit (in areas accessible to the general public), the site is generally considered compliant and on-site measurements are typically not required. However, should the Departmental officer require additional information on the site's RF exposure compliance, they may direct the applicant to conduct measurements to demonstrate compliance and/or implement mitigation measures.

Step 3: Selection of measurement equipment

Depending on the frequency bands present at the site and the results of the radio environment search, either frequency selective and/or broadband equipment can be selected for on-site measurements.

The far-field distance should be considered when selecting the measurement locations. Normally, if a location is in the far-field of every radiating element present at the site, then E-field measurements are sufficient. Otherwise, for situations where the public has access to the near-field, both the E-field and H-field should be measured.

Steps 4 and 5: Measurement equipment positioning and site characterisation

To determine if time averaging is required for detailed measurements at the site, the surveyor should initiate a characterization of the various transmissions present at the site in order to quantify the temporal variation of the RF signals (see Section 3.2.1).

Note: Through numerous measurement audits, the Department observed that signals are generally non-uniform in the first 2 metres above ground (spatial variation). Therefore, spatial averaging between 0.2 and 1.8 metres above ground, rooftop, etc., is required for all detailed measurements from 100kHz to 3 GHz. When assessing installations at 3 GHz and above, the spatial maximum between 0.2 and 1.8 metres is required (see Section 3.2.3).

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Step 6: Identification of locations ≥ 50% of the UE limits (walkaround)

The locations identified in step 2 may be used as a starting point for the walkaround inspection of the site (see Section 3.2.2). The walkaround should be performed to establish the RF levels at the site and more specifically to identify locations with RF levels ≥ 50% of the UE limits where specific measurements (scanned spatial or detailed spatial) must be performed. The layout of the walkaround will be dependent on the site under consideration and must cover the entire site. The walkaround inspection should normally be based on, but not limited to, locations identified in step 2. In addition, other locations accessible to the general public (e.g. nearby walking trails, viewpoints, resting areas, etc.) must also be covered by the walkaround inspection. Close attention must be paid to publicly accessible areas in close proximity to the guy wire anchor points (minimum clearance for measurements is 20 cm) where high levels of re-radiation can occur.

Measurement equipment uncertainties must be taken into account for the walkaround and detailed measurements below.

Steps 7 to 9: Detailed measurement

On-site measurements should be taken with a clear view of the antennas when possible and at least 20 cm from any objects to avoid coupling effects. Note that for AM sites there are additional requirements outlined in Section 4.2. In the case of rooftop sites, the measurements should be taken, at a minimum, at locations where a member of the general public could be exposed to the main or side lobes of the antennas.

Steps 10 to 12: Induced and contact currents considerations

Induced and contact current measurement considerations are required if the site being surveyed has transmitters operating at 110 MHz or below.

Step 13: Reporting

A comprehensive report should be compiled according to the requirements defined in GL-08.

3.2 Field Strength and Power Density Measurement Procedures

3.2.1 Site Characterization (Temporal Variation)

As indicated in step 5 of Section 3.1, the surveyor should initially characterize the transmission site with regard to the temporal variation of the RF signals. To do so, the survey equipment should be placed (in the far-field) at the location where the highest RF levels are expected based on the theoretical evaluation or quick scan of the area around the site being assessed.

> **Note:** At the chosen location, the signal should be strong enough, at least 10% (including measurement equipment uncertainty) to determine if the signal variation is significant (if applicable). When the RF levels at the site are below 10% of the SC6 uncontrolled environment limit, including measurement equipment uncertainty, it may be difficult to quantify the signal variation. In this case, the surveyor may assume that the field is constant and carry on with scanned spatial averaging measurements as per Section 3.2.3.1 for site information purposes.

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The probe should be installed on a non-conductive tripod at a height of between 1 metre and 1.8 metres above the reference plane where the measurements are taken (ground level, rooftop, etc.)

In order to characterize the temporal variation of the RF signal at site, measurements across the target frequency range are performed continuously over a period of 6 minutes and the average, maximum and minimum field strength (or power density) is recorded. Should the field strength vary by less than or equal to ±20% (or ±36% in the case of power density), the RF signal is considered to be constant and scanned spatial averaging measurements (see Section 3.2.3.1) will be required for the RF exposure assessment. This will normally be encountered for broadcasting sites such as FM stations. Alternatively, should the variation be greater than the thresholds mentioned above, the signal is considered to be temporally variant. In this case, detailed spatial averaging measurements (see Section 3.2.3.2) will be required for the RF exposure assessment.

Note: Transients in the measurement equipment or instantaneous sporadic electrostatic effects can create spikes in the measured RF signal. When determining the signal variations in time, the temporal peaks created by such spikes should not be considered.

An example for the quantification of temporal variation has been provided below:

1) Capture the average, maximum and minimum power density (or electric field strength) across the target frequency range at the test location

2) If the measured average power density from the RF signal is 40% of the SC6 limit, and if the minimum and maximum measured power density is 32% and 51% of the SC6 limit

3) Temporal variation on the upper bound = $\left|\text{Max} - \text{Avg}\right| / \text{Avg} = \left(\left| 51\% - 40\% \right| /40\%\right) = 27.5\%$

4) Temporal variation on the lower bound = $\left|\text{Min} - \text{Avg}\right| / \text{Avg}\left(\left| 32\% - 40\% \right| /40\%\right) = 20\%$

5) Since the maximum temporal variation of 27.5% is less than the threshold of 36%, the RF signal is considered to be constant. In this case RF exposure can be assessed using scanned spatial averaging measurements

3.2.2 Walk-around Inspection

Once the temporal characterization is completed, the surveyor must initiate a walk around of the entire site with the survey equipment, as introduced in Section 3.1, step 6, to identify potential locations for detailed compliance assessment. The results of the theoretical evaluation may be used as a starting point for the walkaround inspection. Normally, the walkaround inspection is done by holding the survey equipment (i.e., probe or antenna) away from the body and pointing towards the installation being assessed. There should be no other object located within a few metres of the surveyor. The height of the survey equipment should be swept vertically in one continuous motion between 0.2 metres and 1.8 metres above ground level or the horizontal reference plane where the measurements are being taken.

The minimum number of detailed measurements required will depend on the number of locations $\geq 50\%$ found during the walk-around inspection as described in the table below.

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Number of locations ≥ 50%	Minimum number of locations for detailed measurements
0 to 4	Highest 4 locations
More than 4	Each location ≥ 50%

As shown in the Table above, if the walkaround inspection reveals 0 - 4 locations with RF exposure levels ≥ 50%, then detailed measurements shall be performed for the highest 4 locations (based on RF exposure level). If the walkaround inspection reveals more the 4 locations with RF exposure levels ≥ 50%, then detailed measurements shall be performed at each location ≥ 50%.

3.2.3 Detailed Measurement

For the measurement locations identified in Section 3.2.2, time and spatial averaging should be performed from 100 kHz to 3 GHz and the spatial maximum should be measured at 3 GHz and above. Depending on the results of the site characterization regarding temporal variation (see Section 3.2.1), time and spatial averaging over a vertical line representing the vertical extent of a human body can either be obtained through a quick scan (see Figure 1) or through a 5-point discrete measurements (see Figure 2) as described in the next two sections.

Note: The surveyor must ensure the proper configuration of the measurement equipment for all SC6 measurements. For example, measurement equipment used in a multi-frequency environment should preferably be capable of summing the normalized exposure levels of all frequencies present by providing the total normalized exposure level. If direct field strength or power density measurements are envisaged, measurements must be done separately for **each frequency**, as the SC6 limits vary with the frequency.

When conducting detailed field strength/power density measurements (e.g. for FM, Digital Radio, VHF/UHF/Digital TV, MDS and cellular transmitting sites), the measurement mode should be set to average root-mean-square (RMS).

3.2.3.1 Time Averaging Not Required (Scanned Spatial Averaging)

If the temporal characterization of the site (see Section 3.2.1) reveals that time averaging measurements are not required, a single continuous sweep with an isotropic probe over the vertical extent of a human body (from 0.2 metres to 1.8 metres) shall be done in order to determine the scanned spatial average value from 100kHz to 3GHz. Normally, continuous scanned spatial averaging for approximately 30 seconds (from 0.2 metres to 1.8 metres) may be considered provided that the probe has a fast response time (i.e. 1 second or less). For probes with a response time greater than 1 second, the speed of the vertical scan shall be such that a minimum of at least 30 samples are taken when performing the scanned spatial averaging measurements.

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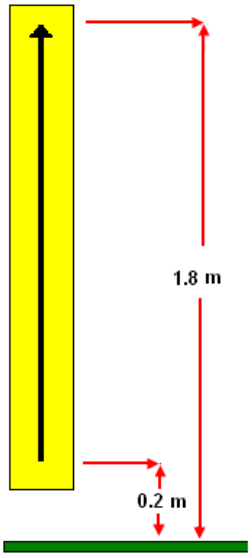

Figure 1: Spatial averaging scan over the vertical extent of a human body (from 20 cm to 1.8 m) for a uniform electric field

> **Note:** If a single axis probe/antenna is being used instead of an isotropic one , all three orthogonal axes will need to be measured separately and summed as per eq. 3.4 below. In most situations, it implies that a detailed spatial averaging will need to be performed.

3.2.3.2 Time Averaging Required (Detailed Spatial Averaging)

If time averaging measurements are required, each point on a 5-point vertical line representing the vertical extent of a human body must be measured and time-averaged over a period of 6 minutes. The 5 points should be evenly spaced (see Figure 2 below). Using the time-averaged value for each point of the 5-point vertical line determined below, the spatial average (for frequencies from 100kHz – 3GHz) is calculated for that specific measurement location by taking the average of the 5 points. The probe shall be set on a non-metallic tripod when performing these detailed spatial averaging measurements.

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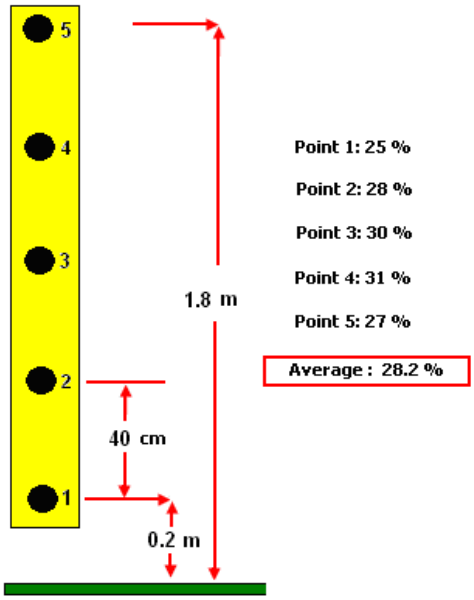

Figure 2: Example of a grid for measurements of a non-uniform signal level and the calculation of the average value as a percentage of SC6 limits(UE)

The following three equations show how to calculate the spatial average using the 5-point vertical line. The first equation (eq. 3.1) is based on equipment that is capable of directly measuring the total exposure in percentage of the limit, whereas the other two equations (eq. 3.2 and eq 3.3) are based respectively on power density and field strength measurements. Measurement equipment uncertainty shall also be considered when applying these equations.

(A) Calculating spatial average (100 kHz – 3 GHz) with total exposure values in normalized percentage:

The test point is compliant if:

$$\frac{1}{5}\sum_{j=1}^{5}\left(\frac{Ex\%_{Avg}}{100}\right)_j \leq 1 \qquad \text{(eq. 3.1)}$$

where: $(Ex\%_{Avg})_j$ is the time-averaged total exposure in normalized percentage at the point j on the vertical line.

Eq. 3.1 should be used for measurements in the far field. This first equation assumes that the equipment is internally using the square of the field values to determine the normalized exposure level.

(B) Calculating spatial average (100 kHz – 3 GHz) using power density measurements:

The test point is compliant if:

$$\sum_{i=1}^{N}\left(\frac{S_{Avg,i}}{S_{SC6,i}}\right) \leq 1 \text{ with } S_{Avgi} = \frac{1}{5}\sum_{j=1}^{5}\left(S_{TAvg,i}\right)_j \qquad \text{(eq. 3.2)}$$

where: N is the total number of frequencies at the site
S_{Avgi} is the spatial average of the power density for the i^{th} frequency
$(S_{TAvg,i})_j$ is the time-averaged power density for the i^{th} frequency and at the point j on the vertical line
$S_{SC6,i}$ is the SC6 power density limit for the i^{th} frequency

Eq. 3.2 can also be used for measurements in the far field only because the equipment is measuring E-Field and converting to power densities using the impedance of free space (377 Ω), which is only true in the far-field.

(C) Calculating spatial average (100 kHz – 3 GHz) using field strength measurements:

The test point is compliant if:

$$\sum_{i=1}^{N}\left(\frac{E_{Avgi}}{E_{SC6,i}}\right)^2 \leq 1 \text{ with } E_{Avgi} = \sqrt{\frac{1}{5}\sum_{j=1}^{5}\left(E_{AvgRMS,i}\right)^2} \qquad \text{(eq. 3.3)}$$

where: N is the total number of frequencies at the site
E_{Avgi} is the spatial average of the field strength for the i^{th} frequency
$(E_{AvgRMS,i})_j$ is the time-averaged RMS field strength for the i^{th} frequency and at the point j on the vertical line
$E_{SC6,i}$ is the SC6 electric field strength limit for the i^{th} frequency

Eq. 3.3 may be used for measurements performed in near-field and far-field regions.

In an environment with multiple frequency bands, the measurement equipment is typically capable of summing the combined exposure values without manual calculation by the user.

If single axis measurements are taken, each 6-minute time-averaged RMS field strength measurement $(E_{AvgRMS,i})_j$ should be evaluated by combining the three axis contributions based on the following equation:

$$(E_{AvgRMS,i})_j = \sqrt{\sum_{k=1}^{3}\left[(E_{AvgRMS,i})_{j,k}\right]^2} \qquad \text{(eq. 3.4)}$$

where: $(E_{AvgRMS,i})_{j,k}$ is the time-averaged RMS field strength for the i^{th} frequency and at the point j on the vertical line along the axis k (k= x, y and z axis).

3.2.3.3 Spatial maximum above 3GHz

When the main RF contributions are from sources above 3GHz, spatial averaging should not be performed given that it may not be conservative enough with respect to peak spatial average SAR limit over 1 gram of tissue. Instead, the spatial maximum across 5 discrete points on a vertical line should be used to assess compliance with Safety Code 6.

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According to the site characterization with respect to temporal variation, if time averaging is not required, discrete measurements at each point on a 5-point vertical line may be considered, representing the vertical extent of the human body. The measurement at each point should be based on the average of a minimum of 10 samples. Of the 5 measurement points, the highest value should be used to compare to the SC6 limit for UE. When time averaging is required, each point on a 5-point vertical line should be measured and time-averaged over a period of 6 minutes (see Figure 2). Of the 5 time-averaged levels measured, only the highest level should be used to compare to the SC6 limits for UE.

In order to demonstrate compliance, the same equations described in Section 3.2.3.2 are applicable except that only the highest of the 5 levels is used as in the following:

(A) Using normalized exposure levels, the test point is compliant if:

$$\frac{Ex\%_{Pk_AvgRMS}}{100} \leq 1 \qquad \text{(eq. 3.5)}$$

where: $Ex\%_{Pk_AvgRMS}$ is the highest of the 5 time-averaged total exposure in normalized percentage among the measurements taken on the vertical line.

Similarly, eq. 3.5 should be used for measurements in the far field. This equation assumes that the equipment is internally using the square of the field values to determine the normalized exposure level.

(B) Using direct measurement of power densities, the total normalized exposure level for each point *j* of the vertical line must first be determined (by adding the normalized contribution for each frequency *i* at that point). Among the 5 points, only the highest value of the total normalized exposure level associated with each point is kept. This highest value should be smaller or equal to 1 in order to ensure compliance with SC6.

Using the following equation, the test point is compliant if:

$$ExNorm_{Pk_AvgRMS} \leq 1 \text{ where } ExNorm_{Pk_AvgRMS} = max_{j=1to5}\left[\sum_{i=1}^{N}\left(\frac{S_{AvgRMS,i,j}}{S_{SC6,i}}\right)\right] \qquad \text{(eq.3.6)}$$

where: *N* is the total number of frequencies at the site
$S_{AvgRMS,i,j}$ is the time-averaged power density for the i^{th} frequency at point *j* on the vertical line
$S_{SC6,i}$ is the SC6 power density limit for the i^{th} frequency
$ExNorm_{Pk_AvgRMS}$ is the highest value among the 5 points on the vertical line of the total normalized exposure level associated with each point.

Again, eq. 3.6 can also be used for measurements in the far field. As the equipment is measuring E-field and converting to power densities using the impedance of free space (377 Ω), which is only true in the far-field.

(C) using direct field measurements, similarly, the total normalized exposure level for each point *j* of the vertical line is first determined (by adding the normalized contribution for each frequency *i* at that point). Among the 5 points, only the highest value of the total normalized exposure level associated with each point is kept. This highest value should be smaller or equal to 1 in order to ensure compliance with

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SC6.

Using the following equation, the test point is compliant if:

$$ExNorm_{Pk_AvgRMS} \leq 1 \text{ where } ExNorm_{Pk_AvgRMS} = max_{j=1to5}\left[\sum_{i=1}^{N}\left(\frac{E_{AvgRMS,i,j}}{E_{SC6,i}}\right)^2\right] \quad \text{(eq. 3.7)}$$

where: N is the total number of frequencies at the site
$E_{AvgRMS,i,j}$ is the time-averaged field strength for the i^{th} frequency at point j on the vertical line
$E_{SC6,i}$ is the SC6 electric field strength limit for the i^{th} frequency
$ExNorm_{Pk_AvgRMS}$ is the highest value among the 5 points on the vertical line of the total normalized exposure level associated with each point.

Finally, eq. 3.7 may be used for measurements performed in near-field and far-field regions.

If single axis measurements are performed, for each point j on the vertical line, the time-averaged field strength of each axis $(E_{AvgRMS,i,j})_k$ is combined (for the i^{th} frequency). The resulting total field strength for that frequency at that point $(E_{AvgRMS,i,j})$ is then compared to the SC6 field strength limit for that frequency $(E_{SC6,i.})$. This gives the normalized exposure level for the i^{th} frequency at point j. The normalized contribution of each frequency at point j is added in order to obtain the total normalized exposure level at point j. This process is repeated for each of the 5 points on the vertical line. Among the 5 points, the highest value of the total exposure level associated with each point is kept. This highest value should be smaller or equal to 1 in order to ensure compliance with SC6.

Using the following equation, the test point is compliant if:

$$ExNorm_{Pk_AvgRMS} \leq 1 \text{ where: } ExNorm_{Pk_AvgRMS} = max_{j=1to5}\left[\sum_{i=1}^{N}\left(\frac{E_{AvgRMSi,j}}{E_{SC6,i}}\right)^2\right]$$

$$\text{and where: } E_{AvgRMS,i,j} = \sqrt{\sum_{k=1}^{3}\left[(E_{AvgRMS,i,j})_k\right]^2} \quad \text{(eq. 3.8)}$$

where: N is the total number of frequencies at the site
$(E_{AvgRMS,i,j})_k$ is the time-averaged field strength for the i^{th} frequency at point j on the vertical line along the axis k (k= x, y and z)
$E_{AvgRMS,i,j}$ is the time-averaged field strength for the i^{th} frequency at point j on the vertical line
$E_{SC6,i}$ is the SC6 electric field strength limit for the i^{th} frequency
$ExNorm_{Pk_AvgRMS}$ is the highest value among the 5 points on the vertical line of the total normalized exposure level associated to each point.

3.2.3.4 Applying Measurement Equipment Uncertainty

As indicated in step 6 of Section 3.1, the measurement equipment uncertainty should be added to each measurement before determining compliance (see Annex B). The following two examples show how to consider the uncertainty of the measurement equipment.

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Example 1:

The meter shows a reading of 25% of the SC6 limit for UE. If the measurement equipment has an uncertainty of ±3 dB, the percentage could be as high as 50% of the SC6 limit for UE. Therefore, the location should be considered for detailed measurements (see Section 3.2.3).

Example 2:

The meter shows a reading of 10% of the SC6 limit for UE. If the measurement equipment has an uncertainty of ±3 dB, the percentage could be as high as 20% of the SC6 limit for UE. Therefore, the location does not need to be considered for detailed measurements.

3.3 Induced and Contact Current Measurement Procedures

Induced and contact current measurement are required if the transmitters within the radio environment have operating frequencies of 110 MHz or below. Within strong RF fields, close attention must be given to metallic objects, including guy-wires and anchor points, as induced and contact currents as well as re-radiated RF emissions can be present at levels which exceed the UE limits. Since neither numerical analysis methods, nor current computational modeling simulations, are able to accurately assess the levels present at these locations, operators of these site may have to conduct measurements in order to demonstrate compliance.

Note: When measuring the levels of RF emissions, induced current, or contact current for the purpose of determining compliance with the UE limits of SC6, the measurement equipment uncertainty must be added to the measured level.

Under certain conditions, the induced current can exceed the limits specified in Table A.4 of Annex A, even though the electric field strengths are below the limits specified in tables A.1 and A.3 of Annex A. These conditions may occur even when the electric field strength is as low as 25% of the exposure limit. Therefore, induced current through a single foot should be measured by using a clamp-on current probe or a low-profile platform consisting of two parallel conductive plates isolated from each other with one located above the other when the electric field is 25% of the UE limit or higher. The initial induced current measurements should be taken at the locations with the highest field strength.
For frequencies between 400 kHz and 110 MHz, a SAR-based induced current limit over a 6-minute reference period should be used and the following steps should be followed when induced current measurements are required and performed with a clamp-on current probe:

(1) The surveyor should visit each location with strong field exposure as identified during the walkaround inspection (see Section 3.2.2 of this guideline). The identified locations should be logged (e.g. photos, geographical coordinates, description of area).

(2) At each location identified in step 1, the surveyor should be standing upright and without touching any metallic objects. The clamp-on probe should be clamped around his/her ankle. The surveyor should modify the position of his/her arms to find the maximum reading. The measurement equipment uncertainty must be added to the measured average RMS current then the square of this value is compared to the square of the induced current limit for UE specified in Table A.4 of Annex A. If time averaging is required based on the site characterization (temporal variation) described in

Section 3.2.1, the average RMS value should be obtained over a reference period of 6 minutes, otherwise 30 seconds is considered sufficient (see note below).

Similarly, the contact current can exceed the current limits specified in Table A.5 of Annex A, even though the electric field strengths, which are the major contributor to the contact current, are below the limits as specified in tables A.1 and A.3 of Annex A. These conditions may occur when the electric field strength is as low as 25% of the exposure limit. For any conducting metallic object that a person may come in contact with and that is located in a high-intensity RF field, contact currents should be measured when the electric field strength is 25% of the UE limits or higher. An electric circuit having the impedance of the human body or a clamp-on current probe should be used for measurements.

For frequencies between 100 kHz and 10 MHz (e.g. AM stations), a SAR-based contact current limit with an instantaneous reference period should be used. As such, a measurement time of approximately 30 seconds may be considered to evaluate the **maximum** RMS contact current (including measurement equipment uncertainty). However, depending on the site characterization (temporal variation), the measurement time may be extended to 6 minutes to ensure that the maximum RMS value is captured. To assess compliance, the square of the maximum RMS value (obtained over either the 6-minute or 30-second time period) should be compared to the square of the SAR-based contact current limit specified in Table A.5.

For frequencies between 10 MHz and 110 MHz (e.g. FM and television transmitting sites (TV channels 2 to 6)), a SAR-based contact current limit with a 6-minute reference period should be used. As such, the clamp-on probe should be set to **average** RMS and the square of the measured contact current value (including measurement equipment uncertainty) should be compared with the square of the SAR-based contact current limit specified in Table A.5. If time averaging is required based on the site characterization (temporal variation) described in Section 3.2.1, the average RMS value should be obtained over a reference period of 6 minutes, otherwise 30 seconds is considered sufficient (see note below).

The following steps should be followed when contact current measurements are required and performed with a contact current probe.

> **Note:** For any conducting metallic object located near a **high-intensity** RF field source such as AM installations, the measurements should not be performed using the clamp-on current probe given that the measurements results could be excessively over the contact current limits for the controlled environment and pose a risk to the surveyor.

(1) Perform a visual inspection of the area around the antenna site for conductive object that can be accessible to the general public. The identified locations should be logged (e.g. photos, geographical coordinates, description of structure).

(2) Conduct E-field or H-field measurements near the conductive object no closer than the recommended minimum separation distances (e.g. 20 cm). If the applicable E-field or H-field limits are exceeded, then the conductive object should be deemed to be an over-exposure point (non-compliance) and no further measurements are required. Otherwise, proceed to step 3 and use a contact current probe.

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(3) Determine the contact current by following the operational guidelines of the measurement equipment for a continuous reference period of 6 minutes or 30 seconds as described in the second note below and compare the square of the measured average or maximum RMS contact current (including measurement equipment uncertainty) with the square of the contact current limit for UE specified in Table A.5.

Note: Some contact current instrument, such as clamp-on probe around the wrist, may require the surveyor to be part of the circuit. In these situations, for additional precaution, the surveyor may opt to wear an insulating glove (fabric or rubber) prior to touching the structure under test with the index. If the contact current limits are exceeded wearing the glove, then the conductive object should be deemed to be an over-exposure point (non-compliance) and no further measurements are required. However, if the contact current is within the limits, repeat the measurement without the glove as described in step 3.

Note: A continuous reference period of 6 minutes is applicable for frequencies between 400 kHz and 110 MHz for induced current limits (see Table A.4 of Annex A) and between 10 and 110 MHz for contact current limits (see Table A.5 of Annex A). Consequently, the site characterization with respect to temporal variation (see Section 3.2.1) will determine if time averaging is required. When time averaging is required, the average RMS induced and contact current measurements will be determined over a continuous reference period of 6 minutes. When time averaging is not required, the average RMS induced and contact current measurements may be determined over a continuous reference period of 30 seconds. However, if the induced and contact current measurement values vary significantly (e.g. more than ±20%) in spite of the site characterization (temporal variation), the averaging time should be expanded to 6 minutes.

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4.0 Specific Measurements Procedures

This section provides the measurement procedures for specific types of transmitting sites. Unless otherwise specified, the general measurement procedures detailed in Section 3 are applicable.

4.1 Measurement Procedures for FM, Digital Radio, VHF/UHF/Digital TV and MDS Transmitting Sites

The general measurement procedures, described in Section 3, for verifying compliance with SC6 are applicable to FM, digital radio, VHH/UHF/digital TV and MDS transmitting sites.

In the case of induced and contact currents, measurement considerations are required if transmitters within the environment in question have operating frequencies below 110 MHz (see Section 3.3).

4.2 Measurement Procedures for AM Transmitting Sites

Both NS-based and SAR-based field strength limits and current limits may apply to an AM station depending on its operating frequency (see tables A.1, A.2, A.4 and A.5 of Annex A). Therefore, the applicable reference periods will either be instantaneous or 6 minutes. In this document, instantaneous reference periods are considered by capturing the maximum RMS field or maximum RMS current values normally over a period of 30 seconds, whereas a 6-minute reference period implies the measurement of the average RMS field or average RMS current values over this time period. As RF measurements for AM stations are typically taken in the near-field region, both electric and magnetic field strengths should be measured when performing detailed measurements. In addition, measurements shall be done using a non-metallic tripod and a minimum of at least 5 metres separation should be maintained between the measuring equipment and the surveyor to minimize the impact of the surveyor on the results. When performing the measurements, it is recommended to use a fibre optic cable to link the probe to the main surveying equipment.

Due to the distances between the radiators (towers) in AM arrays, each tower must be assessed separately. For each tower, a practical radial distance can be established, where measurement can begin and proceed towards the tower up to the point where public access is restricted (see AM procedure in BPR-1). Fifty percent (50%) of the most stringent electric and magnetic field strength limit (lower value) between the NS-based limit and the SAR-based limit should be selected (see tables A.1 and A.2 in Annex A) when determining the initial measurement distance based on the AM procedure described in BPR-1. When the BPR-1 method is used, the measurement zone for each tower should be determined using the proposed transmitter power at its base. Although this is only an approximate method, it is sufficiently accurate in most cases.

The SC6 UE limits are typically found to lie along a locus generally circular or slightly egg-shaped around the foot of each tower. For a detailed measurement, a minimum of four (4) readings should be taken along each radial for each tower, moving inwards from the maximum measurement radius. In general, only the tower with the highest radiated power needs to be considered. If SC6 limits for UE are exceeded in areas accessible to the general public for tower, the other towers will need to be considered in order of decreasing tower radiated power. The calculated measurement radius may need to be extended if readings at the starting point already exceed the SC6 limit for UE.

As indicated above, SAR-based and NS-based field strength limits may apply depending on the

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operating frequency of the AM station. Section 3.2 should be referenced when determining compliance with SAR-based field strength limits. As the radiated power from an AM station varies with modulation, continuous time averaging measurement over 6 minutes will likely be required. However, site characterization with respect to temporal variation (see Section 3.2.1) will confirm whether time averaging is needed. If time averaging is not required, the measurement time may be reduced to 30 seconds. To assess compliance, with SAR-based limits, the average of the squares of the average RMS field strength value (obtained over either the 6-minute or 30-second time period) taken for each of the points on the 5-point vertical line should be compared to the square of the SAR-based field strength limit (see note below for the calculations).

For NS-based field strength limits, the site characterization, the walkaround inspection and the spatial averaging methodology of sections 3.2.1 to 3.2.3 are also applicable. As Safety Code 6 requires an instantaneous reference period to assess compliance with NS-based field strength limits, the maximum RMS field strength over a measurement time of approximately 30 seconds should be measured. However, depending on the site characterization (temporal variation), the measurement time may be extended to 6 minutes to ensure that the maximum RMS value is captured. To assess compliance, with the NS-based limits, the average of the maximum RMS field strength value (obtained over either the 6-minute or 30-second time period) taken for each of the points on the 5-point vertical line should be compared to the NS-based field strength limit (see note below for the calculations).

Note: For **NS-based limits**, the spatial average is performed by summing the 5 spatial samples of field strengths arithmetically and dividing the result by the number of samples. In the following equation, a single operating frequency is considered. However, the equation is also valid for multiple frequencies if the applicable SC6 limit is the same for all frequencies.

$$\frac{E_{NS}}{E_{SC6-NS}} \leq 1 \text{ to comply with the limits and where } E_{NS} = \frac{1}{5}\sum_{j=1}^{5}(E_{MaxRMS})_j \qquad \text{(eq. 4.1)}$$

In the above equation, $(E_{MaxRMS})_j$ is the maximum RMS E-field strength at the point *j* on the vertical line and $E_{SC6\text{-}NS}$ is the NS-based SC6 limit for the E-field. The same equation applies to H-field measurements.

If single axis probes are used, the 3 axis measurements must be combined as follows:

$$(E_{MaxRMS})_j = \sqrt{\sum_{k=1}^{3}\left[(E_{MaxRMS})_{j,k}\right]^2} \qquad \text{(eq. 4.2)}$$

where: $(E_{MaxRMS})_{j,k}$ is the maximum RMS E-field at the point *j* on the vertical line along the axis *k* (*k*=*x*, *y* and *z* axis).

Finally, for a site with multiple frequencies and multiple applicable SC6 limits when using a single axis probe, the following general equations are used where *i* denotes the i^{th} group of frequencies having the same NS-based SC6 limit $E_{SC6\text{-}NS,i}$:

$$\sum_{i=1}^{N}\left[\frac{E_{NS,i}}{E_{SC6-NS,i}}\right] \leq 1 \text{ with} E_{NS,i} = \frac{1}{5}\sum_{j=1}^{5}(E_{MaxRMS,i})_j \text{and with} (E_{MaxRMS,i})_j = \sqrt{\sum_{k=1}^{3}\left[(E_{MaxRMS,i})_{j,k}\right]^2} \quad \text{(eq.4.3)}$$

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For **SAR-based limits**, spatial averaging value is based on an RMS calculation of measured field strengths. As indicated above, time-averaged RMS field strength measurements over 6 minutes will also likely be required for AM stations when performing SAR-based measurements. The following general equation applies where the indexes have the same definitions as the above equations and where the SAR-based SC6 limit for the i^{th} group of frequencies having the same limit is represented by $E_{SC6\text{-}SAR,i}$:

$$\sum_{i-1}^{N}\left[\left(\frac{E_{SAR,i}}{E_{SC6-SAR,i}}\right)^2\right] \leq 1 \text{ with} E_{SAR,i} = \sqrt{\frac{1}{5}\sum_{j=1}^{5}\left[(E_{AvgRMS,i})_j\right]^2} \text{ and with} (E_{AvgRMS,i})_j = \sqrt{.\sum_{k=1}^{3}\left[(E_{AvgRMS,i})_{j,k}\right]^2} \quad \text{(eq. 4.4)}$$

The same equations apply to NS- and SAR-based H-field measurements.

For AM stations, both induced and contact current measurements should also be taken. The measurement procedures detailed in Section 3.3 should be referenced for the measurement steps. For contact current, given that instantaneous SAR-based measurements are required for AM stations operating frequencies, a measurement time of approximately 30 seconds may be considered to evaluate the maximum RMS contact current. However, depending on the site characterization with respect to temporal variation (see Section 3.2.1), the measurement time may be extended to 6 minutes to ensure that the maximum RMS value is captured. To assess compliance, the square of the maximum RMS value (obtained over either the 6-minute or 30-second time period) should be compared to the square of the SAR-based contact current limit. For the induced current, an SAR-based limit also applies, but the reference period is 6 minutes. However, site characterization with respect to temporal variation (see Section 3.2.1) will confirm whether time averaging over 6 minutes is needed. If not, the averaging time may be reduced to 30 seconds. To assess compliance, the square of the average RMS value (obtained over either the 6-minute or 30-second time period) should be compared to the square of the SAR-based induced current limit.

4.3 Measurement Procedures for Microwave Transmitting Sites (Fixed Point-to-Point)

When field strength measurements are required for microwave transmitting sites, the following considerations are applicable:

If the radiator is not highly directional (i.e. beamwidth > 5 degrees), assume that far-field conditions exist beyond a one-metre distance for frequencies above 300 MHz. If it is estimated that far-field conditions exist, SC6 permits the measurement of E, H or power density (PD).

If it is estimated that near-field conditions exist, SC6 requires separate E and H measurements within the operating range of commercially available survey equipment. However, if it is unknown whether near-field or far-field conditions exist, then the surveyor should assume near-field conditions and measure both E- and H-fields separately.

The measurement procedures described in Section 3 for determining SC6 compliance are also applicable for microwave transmitting sites, excluding the induced and contact current measurements, which are

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not applicable to frequency ranges above 110 MHz.

4.4 Measurement Procedures for Land Mobile, Cellular and Microwave Point-to-Multipoint Transmitting Sites

This section applies to transmitting facilities involving land mobile, cellular and microwave point-to-multipoint services operating at frequencies above 10 MHz.

The general measurement procedures described in Section 3 for determining SC6 compliance are also applicable to these types of sites. In cases of induced and contact currents (see Section 3.3), measurement considerations are required if transmitters within the environment in question use operating frequencies at or below 110 MHz .

For cellular transmitting sites, the complexity in performing field measurements representing the worst-case exposure condition depends with the technologies employed, number of frequencies, operators and traffic load. For some complex cellular transmitting sites, computational modelling, may be used as an alternative to demonstrate RF exposure compliance.

It is noted that traffic patterns may vary across cellular networks based on factors such as population density, time of day, special events etc. Hence, the theoretical maximum transmitted power or EIRP for RF exposure compliance assessments may be overly conservative and could lead to large compliance boundaries. In order to reflect a more realistic RF exposure condition, the actual maximum transmitted power or EIRP (which is a function of the network traffic load) may be used instead. This approach may be considered, provided that the base station remains compliant (using power limiting mechanisms) even with increases in the network traffic load. As such, computational assessments based on the actual maximum transmitted power or EIRP may be considered only if implemented along with power limiting mechanisms on the base station. The successful network implementation of such power limiting mechanisms must first be demonstrated (accounting for various deployment configurations) to the department based on sound engineering practices before being accepted. The validation of such mechanisms should clearly show that traffic load variations do not increase RF exposure at the measurement location. This will involve comparing the RF exposure at various load levels with and without the power limiting mechanism activated.

Should the computational model indicate that the contribution of cellular (specifically 4G and 5G) service to the overall RF exposure is greater than 50% of the SC6 UE limit, then specific measurements may be requested, taking into account the worst case configuration for the site. The principles for the worst case measurement procedure have described in Annex C.

4.4.1 Underground base station/antenna installations

Underground base station/antenna installation such as those used by cellular carriers integrated into manhole covers or other similar deployment will be assessed differently than typical cellular antenna installations. Since a person could actually be in contact with antennas deployed in this manner by standing on it or be located within 20 cm of such antenna, a SAR evaluation would be required. This will normally be done as part of this antenna system's certification process which is not in scope of GL-01. In addition to the SAR evaluation, the general measurement procedures described in Section 3

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should be used to demonstrate the E- and H-fields stemming for these installations are in compliance with the SC6 limits for UE.

4.5 Measurement Procedures for Radar Transmitting Sites

The measurement procedures described in Section 3 for determining SC6 compliance also apply to these types of sites. To ensure general public protection, measurements must be performed under the worst case operational mode of the radar considering parameters such as: stationary mode vs rotational mode, tilt angle and vertical movement, pulse duty cycle (e.g. pulse duration and repetition frequency), rotational duty cycle (rotation speed, beam width), etc.

When measurements are conducted on a scanning/rotating antenna, the survey equipment must be appropriately selected in order for the equipment integration time (response time) is smaller than the radar illumination time during signal sweeps (time on target). Otherwise, the measured exposure levels may have to be adjusted.

In addition to average power measurements, SC6 also specifies limits over the pulse duration that must be verified for compliance. The limit in power density over the pulse duration is 1000 times the applicable power density reference level. Similarly, the limit for the squared electric and magnetic fields and the squared induced and contact currents over the pulse duration is 1000 times the applicable squared reference level. Please refer to the Notes referenced in SC6 tables 5, 6, 7 and 8 for further details.

When measurements are planned at radar sites, special care must be taken due to the possibility of extremely high powers involved.

In cases where there is a predicted or known risk of overexposure to survey personnel, one of the following four survey approaches may be used depending on the risk assessment:

(a) For high-risk cases, a horn antenna can be placed inside the measurement area (while the radar transmitter is OFF) and connected to a spectrum analyzer with a low-loss cable of sufficient length to permit data to be taken without risk of overexposure. An attenuator may be required to protect the spectrum analyzer from possible damage.

(b) For medium-risk cases, survey equipment may be placed on a tripod inside the measurement area (while the radar transmitter is OFF) and the meter is read with binoculars or via an optical link.

(c) For low-risk cases, the survey probe may be used for an initial assessment.

(d) Alternately, where it is not necessary that the transmitter operate at full power, the transmitter may be operated at a reduced power level and the data adjusted to take into account this power reduction.

Where test procedures require a stationary radar beam, by precaution, personnel must be vacated from inhabited areas that will be radiated by, either the main beam, or secondary lobes or reflections from the

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main beam or secondary lobes.

For measurements on a scanning/rotating antenna, ensure that there is sufficient clearance between a scanning/rotating antenna and survey personnel to avoid physical injury. Throughout the survey, survey personnel should be in constant communication with the radar operator in order to implement parameter changes required by the test program and to be able to quickly curtail transmitter operation in case of emergency.

5.0 Reporting Requirements

GL-08, *Guidelines for the Preparation of Radio Frequency (RF) Exposure Compliance Reports for Radiocommunication and Broadcasting Antenna Systems*, should be used when reporting the RF exposure measurement survey.

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References

The following documents are indispensable for the application of this document and should therefore be consulted when performing measurements of RF fields:

1) Health Canada's *Limits of Human Exposure to Radiofrequency Electromagnetic Energy in the Frequency Range from 3 kHz to 300 GHz – Safety Code 6*

2) Health Canada's *Technical Guide for Interpretation and Compliance Assessment of Health Canada's Radiofrequency Exposure Guidelines*

3) Broadcasting Procedures and Rules BPR-1, *General Rules*

4) Client Procedures Circular CPC-2-0-03, *Radiocommunication and Broadcasting Antenna Systems*

5) Client Procedures Circular CPC-2-0-20, *Radio Frequency (RF) Fields – Sign and Access Control*

6) Guidelines GL-08, *Guidelines for the Preparation of Radio Frequency (RF) Exposure Compliance Reports for Radiocommunication and Broadcasting Antenna Systems*

7) Radio Standards Specifications RSS-102, *Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)*

8) Technical Note TN-261, *Safety Code 6 (SC6) Radio Frequency Exposure Compliance Evaluation Template (Uncontrolled Environment Exposure Limits)*

9) IEC 62232, *Determination of RF field strength and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure*

10) IEEE C95.3, *Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields with Respect to Human Exposure to Such Fields, 100 kHz-300 GHz*

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Annex A — Reference Levels for Safety Code 6 (SC6) Limits for Uncontrolled Environments (UE)

Table A.1 – Electric Field Strength Limits for the UE From 3 kHz to 10 MHz

Frequency Range	Electric Field Strength (V/m RMS)	Reference Period	Basis for Limit
0.003-10 MHz	83	Instantaneous	Based on Nerve Stimulation
1.1 - 10 MHz	$87/f^{0.5}$	6 min	Based on Specific Absorption Rate

Note: Frequency, f, is in MHz

Table A.2 – Magnetic Field Strength Limits for the UE From 3 kHz to 10 MHz

Frequency Range	Magnetic Field Strength (A/m RMS)	Reference Period	Basis for Limit
0.003-10 MHz	90	Instantaneous	Based on Nerve Stimulation
0.1 - 10 MHz	0.73/f	6 min	Based on Specific Absorption Rate

Note: Frequency, f, is in MHz

Table A.3 – Field Strength/Power Density Limits for the UE From 10 MHz to 300 GHz

Frequency Range	Electric Field Strength (V/m RMS)	Magnetic Field Strength (A/m RMS)	Power Density (W/m^2)	Reference Period (minutes)
10 - 20 MHz	27.46	0.0728	2	6
20- 48 MHz	$58.07/f^{0.25}$	$0.1540/f^{0.25}$	$8.944/f^{0.5}$	6
48 - 300 MHz	22.06	0.05852	1.291	6
300 – 6 000 MHz	$3.142f^{0.3417}$	$0.008335f^{0.3417}$	$0.02619\ f^{0.6834}$	6
6 000 – 15 000 MHz	61.4	0.163	10	6
15 000 – 150 000 MHz	61.4	0.163	10	$616000/f^{1.2}$
150 000 – 300 000 MHz	$0.158f^{0.5}$	$4.21 \times 10^{-4}f^{0.5}$	$6.67 \times 10^{-5}f$	$616000/f^{1.2}$

Note: Frequency, f, is in MHz

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Table A.4 – Induced Current Limits for the UE

Frequency Range (MHz)	Induced Current (mA, RMS) Through a Single Foot	Reference Period	Note
0.003 - 0.4	100 f	Instantaneous	Based on Nerve Stimulation
0.4 - 110	40	6 min	Based on Specific Absorption Rate

Note 1: Where the assessment is made of the current flowing through both feet, the results shall be compared to twice the limits for a single foot.

Note 2: Frequency, f, is in MHz.

Table A.5 – Contact Current Limits for the UE

Frequency Range (MHz)	Contact Current (mA, RMS) for Finger-Touch	Reference Period	Note
0.003 - 0.1	200 f	Instantaneous	Based on Nerve Stimulation
0.1 - 10	20	Instantaneous	Based on Specific Absorption Rate
10 - 110	20	6 min	Based on Specific Absorption Rate

Note: Frequency, f, is in MHz

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Annex B — Measurement Equipment Uncertainties

Measurement Uncertainties

Measurement uncertainties are the result of actual measurement uncertainties and/or equipment uncertainties.

Related Documents

For additional information on measurement uncertainties, refer to *Measurement Good Practice Guide*s by the National Physical Laboratory.

Actual Measurement Uncertainties

Actual measurement uncertainties can be minimized by following proper measuring practices and procedures.

Measurement Equipment Uncertainties

Measurement equipment uncertainties are primarily due to the design of the equipment. They can also be affected by other factors, such as environmental conditions, temperature, humidity, etc. Proper calibration of the equipment can largely eliminate the bias errors and a careful selection of equipment type and measuring method can reduce the value of this uncertainty factor.

Requirements for Compliance with Safety Code 6

a. The equipment selected must be of recognized commercial type.

b.Proper calibration of the equipment must be performed in accordance with the manufacturers' recommended calibration period.

c. Correct measurement procedures must be followed.

If the measured RF levels plus the manufacturers' specified measurement equipment uncertainty factor are below the Safety Code 6 (SC6) limits for uncontrolled environments, these exposure levels will be accepted as measured and the site is deemed to be SC6 compliant.

If the measured RF levels plus the manufacturers' specified measurement equipment uncertainty factor exceed the SC6 limits for uncontrolled environments, then corrective remedies must be taken to comply with SC6 requirements (see Client Procedures Circular CPC-2-0-20, *Radio Frequency (RF) Fields – Sign and Access Control*). Alternatively, single frequency measurement of all frequencies present at the site can be conducted and summed together as described in Health Canada's Technical Guide and detailed in this document to improve the measurement equipment uncertainty factor.

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Annex C – Worst case measurement procedures for Cellular base stations

RF exposure from 4G and 5G cellular base stations can vary depending on the traffic load. Generating worst case RF exposure conditions in the field requires maximizing traffic loading on the base station(s) or sector(s) being assessed. In addition, for cellular base stations that incorporate massive MIMO antenna systems with beamforming capabilities, measuring the worst case RF exposure is typically achieved by directing the high gain traffic beam(s) towards the surveyor.

The worst case RF exposure for 4G and 5G cellular transmitting sites may be assessed in field using one of the following approaches:

1) Using dedicated user equipment (e.g. smartphone)

2) Using base station features

Measurement Procedures using dedicated user equipment

In order to generate the worst case RF exposure from a base station without detailed knowledge of network parameters, user equipment running a continuous full buffer downlink traffic session (e.g.: iPerf session or downloading a large file over ftp) may be used by the surveyor based on the principles outlined below.

1. Setup field measurement equipment at the location of interest that was identified through calculations or computations.
2. Perform site characterization as per section 3.2.1
3. Run a baseline measurement as detailed in section 3.2.3 and record the RF exposure
4. Place the user equipment at least 2m from the measurement equipment and ensure that it is locked to the operating frequency being assessed
5. Generate full buffer downlink traffic on the target operating frequency using a suitable application (e.g.: iPerf or ftp) on the user equipment
6. Confirm that the measured operating frequency is loaded by comparing with the result obtained in Step 3 or using BS counters
7. Perform a detailed RF exposure measurement as detailed in section 3.2. with full buffer downlink traffic
8. Ensure that continuous downlink traffic is triggered by the user equipment for the entire duration of the test
9. Repeat steps 1 – 8 for each operating frequency present at the test location
10. In the measurement report capture the following metrics, in addition to those outlined in GL-08:
    a. Baseline RF exposure measurement
    b. RF exposure with user equipment traffic
    c. Application used to generate traffic load

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Measurement Procedures using base station features

Base station features can also be used to generate worst case RF exposure conditions in field by directing a high gain traffic beam at maximum downlink traffic load towards the location under test. The principles to assess worst case RF exposure using base station features have been detailed below:

1) Setup field measurement gear at the location of interest that was identified through calculations or computations. Perform site characterization as per section 3.2.1
2) Run a baseline measurement as detailed in section 3.2.3 and record the RF exposure
3) Simulate 100% downlink physical resource block loading on the frequency band being assessed using base station features
4) If the base station utilizes massive MIMO antennas with beamforming, leverage base station features to direct the traffic beam towards the measurement location. This will likely be an iterative process where the surveyor monitors the signal strength as the base station sweeps the traffic beam across its coverage area
5) Once the worst case configuration has been implemented, perform a detailed RF exposure measurement as detailed in section 3.2.3
6) Repeat steps 1 – 5 for each operating frequency being measured
7) In the measurement report capture the following metrics, in addition to those outlined in GL-08:
    a. Baseline RF exposure measurement
    b. RF exposure with base station features
    c. Any relevant base station parameters (% load, beam azimuth and tilt)

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