

**Case studies supporting IEC
62232 — Determination of
RF field strength and
SAR in the vicinity of
radiocommunication base
stations for the purpose of
evaluating human exposure**

National foreword

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TECHNICAL REPORT



Case studies supporting IEC 62232 – Determination of RF field strength and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**CASE STUDIES SUPPORTING IEC 62232 –
DETERMINATION OF RF FIELD STRENGTH AND SAR IN THE VICINITY
OF RADIOCOMMUNICATION BASE STATIONS FOR THE PURPOSE
OF EVALUATING HUMAN EXPOSURE**

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IEC 62669, which is a technical report, has been prepared by IEC technical committee 106: Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure.

This publication contains attached files in the form of a CD-ROM for the paper version and embedded files for the electronic version. These files are intended to be used as a complement and do not form an integral part of the technical report.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
106/199/DTR	106/208/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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INTRODUCTION

This technical report contains a series of case studies for the evaluation of electromagnetic (EM) sources in the frequency range 100 kHz - 300 GHz to support the methods detailed in the international standard IEC 62232, *Determination of RF field strength and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure*. Using the methods detailed in the standard, each case study has been chosen to illustrate a typical radio base station (RBS) evaluation scenario.

CASE STUDIES SUPPORTING IEC 62232 – DETERMINATION OF RF FIELD STRENGTH AND SAR IN THE VICINITY OF RADIOCOMMUNICATION BASE STATIONS FOR THE PURPOSE OF EVALUATING HUMAN EXPOSURE

1 Scope

This technical report presents a series of case studies in which electromagnetic (EM) fields are evaluated in accordance with IEC 62232. It also provides a reporting template cross referenced to IEC 62232.

Each case study has been chosen to illustrate a typical radio base station (RBS) evaluation scenario and employs the methods detailed in IEC 62232. Some of the case studies demonstrate more than one evaluation method. However, in most situations only one method would be required to complete an evaluation.

The case studies documented in this report are provided for guidance only and are not a substitute for a thorough understanding of the requirements of IEC 62232.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

3 Terms, definitions, symbols and abbreviated terms

For the purposes of this document, the terms, definitions, symbols and abbreviated terms given in IEC 62232 apply.

4 Overview of case studies

4.1 Case study synopsis

This clause provides a summary of worked evaluation examples at a number of RBS sites using a range of methods described in IEC 62232. The example sites include roof-tops, towers, poles, micro cells and in-building cells.

The case studies have been chosen to illustrate typical RBS sites and common evaluations. Some of the case studies demonstrate multiple evaluation methods. However in most situations only one method would be required to complete an evaluation.

NOTE The coloured left-side page margins in the annexes indicates the pages are unchanged versions of sample RF exposure evaluation reports contributed by TC 106 project team members.

4.2 Micro cell case study

The purpose of this case study was to evaluate the RF exposure compliance boundaries from a particular micro cell installation on a building wall to determine whether they would extend to a nearby awning. Compliance boundaries were determined based on a) basic restrictions and b) reference levels to determine the minimum distance from the antenna to the compliance boundary.

The maximum values were compared against international safety guidelines known as ICNIRP (International Commission on Non-Ionizing Radiation Protection) guidelines. The assessment establishes compliance against the basic restrictions known as specific absorption rate (SAR) and the spatially averaged field strength reference levels. SAR testing was performed in a laboratory and frequency selective field measurements were performed on site.

The equipment under test (EUT) was categorised as a simple RBS due to the single technology and single antenna of the micro cell. Nearby base stations, known as secondary sources, had negligible impact on both SAR and field strength evaluations.

The measured SAR and field strength levels were extrapolated to assess the maximum power configuration for the site.

The “best estimate” uncertainty model was applied and the measured levels are reported including the extrapolation for maximum base station power configuration. The uncertainty is stated for all assessment methods used.

The compliance boundary distance for general public exposure using the on-site field strength measurement was 0,8 m and 0,08 m using the SAR evaluation.

Both the SAR evaluation and the on-site field strength measurements confirm that the general public exposure compliance boundary from the micro cell antenna does not extend onto the building awning, therefore access is permitted on the awning.

This case study illustrates:

- the benefit of conducting a SAR evaluation on the small micro cell antenna to minimise its exclusion zone;
- evaluation of RF fields from cellular base station antennas located in close proximity to a roof-top awning accessible to maintenance staff.

Figure 1 shows the surveyor and the micro cell antenna installed on the building wall in Stockholm. The case study is available in full in Annex A.

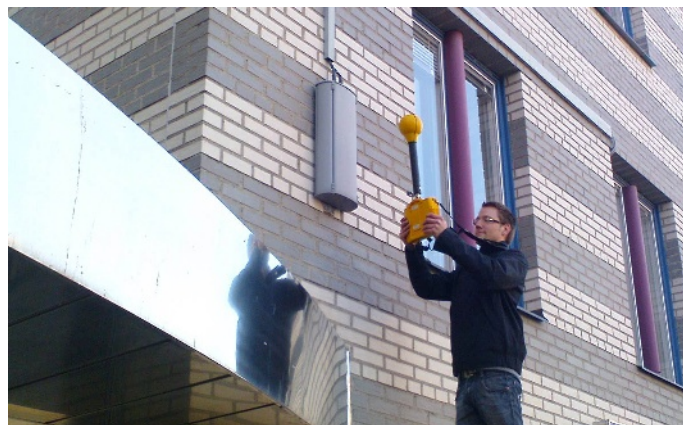


Figure 1 – Micro cell case study

4.3 Roof-top case study with nearby apartment buildings

The purpose of this case study was to verify the RF exposure levels in the accessible areas of an office building roof-top with a cellular base station are below the uncontrolled environment exposure limits in Health Canada's Safety Code 6 Guidelines. The building roof-top has cellular base station panel antennas from two separate operators, and is located near an apartment building, residential and commercial areas.

The equipment under test (EUT) was categorised as a Complex RBS as there are multiple antenna systems at the site under evaluation.

This evaluation was performed by Industry Canada as part of their regulatory auditing program of radio communication and broadcasting sites. The evaluation consisted of computational modelling to determine the RF exposure compliance boundaries around the antennas, and on-site frequency selective field strength measurements to determine the RF exposure levels in accessible areas.

The RF exposure compliance boundary (uncontrolled environment) was assessed to be 6 m directly in front of the panel antennas.

The maximum exposure level on the building roof-top was assessed to be 5,1% of Safety Code 6 limits for the uncontrolled environment. This was on the southwest side of the roof-top underneath the cellular base station panel antennas. The maximum exposure level on the building adjacent to the base station was assessed to be 0,51% of Safety Code 6 limits for the uncontrolled environment. This was on the roof-top car park.

Results are presented for this case study using both the best estimate and upper 95 % CI assessment schemes. The exposure levels reported using the upper 95 % CI assessment scheme i.e. including the measurement equipment expanded uncertainty in the reported level. The exposure levels reported using the best estimate assessment scheme state the actual level evaluated and the uncertainty factor for the measurement equipment.

This case study illustrates:

- evaluation of RF field strength from cellular base station antennas which are mounted on the roof-top of an office building and are accessible to maintenance workers;
- evaluation of RF field strength from cellular base stations which are located near an apartment building, residential and commercial areas;
- full compliance assessment of the site is achieved even if accessibility to certain locations was not possible;
- the results of two spatial averaging schemes are compared.

Figure 2 (left) shows the roof-top installation from a position across the street; while Figure 2 (right) shows the surveyor and base station antennas in-situ. The building is located in Montreal. The case study is available in full in Annex B.

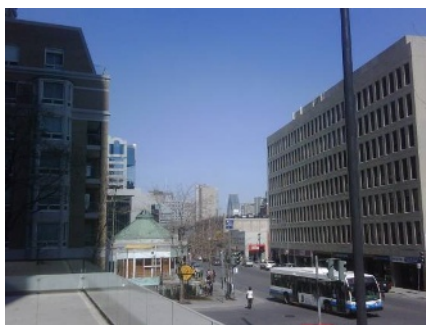


Figure 2 – Roof-top case study with nearby apartment buildings

4.4 Roof-top / tower case study in residential area

The purpose of this case study was to verify RF exposure compliance in a residential and commercial area surrounding a building with a roof-top cellular base station and satellite broadcast radio repeater. The antenna structure is mounted on the second level roof-top of an office building. The equipment under test (EUT) was categorised as a Complex RBS as there are multiple antenna systems at the site under evaluation.

This assessment compared the results of the evaluations against limits set forth in Health Canada's Safety Code 6 guidelines. This compliance assessment was performed by Industry Canada as part of their regulatory auditing program of radio communication and broadcasting sites. The evaluations consisted of computational modelling to determine the RF exposure compliance boundaries around the antennas, and frequency selective field strength measurements to determine the RF exposure levels in the surrounding residential and commercial areas. The accessible areas of the roof-top were also measured.

The RF exposure compliance boundary (uncontrolled environment) was assessed to be 4 m directly in front of the cellular panel antennas, and 2 m directly in front of the satellite broadcast repeater antenna.

The maximum exposure level on the building roof-top was assessed to be 23,92 % of Safety Code 6 limits for the uncontrolled environment which was located a few meters in front of the satellite broadcasting repeater. This location is not accessible to the general public. The maximum exposure level in the residential and commercial areas around the building was assessed to be 0,044 % of Safety Code 6 limits for the uncontrolled environment.

Results are presented for this case study using both the best estimate and upper 95 % CI assessment schemes. The exposure levels reported using the upper 95 % CI assessment scheme include the measurement equipment expanded uncertainty in the reported level. The exposure levels reported using the best estimate assessment scheme state the actual level assessed and the uncertainty factor for the measurement equipment.

This case study illustrates:

- evaluation of RF field strength from cellular base station antennas and satellite broadcast radio repeater which are mounted on a multi-storey building, which houses a centre for continuing education;
- evaluation of RF field strength from cellular base station signals in a residential area;
- the comparison of the results of two (2) spatial averaging schemes.

Figure 3 shows the building in Montreal, which is subject of the evaluation; Figure 3 (left) is wide shot of the environment surrounding the building, while a close-up of the structure and antennas is shown in Figure 3 (right). The case study is available in full in Annex C.



Figure 3 – Roof-top / tower case study in residential area

4.5 Roof-top case study with direct access to antennas

The purpose of this case study was to determine the RF exposure compliance and control boundaries around an operational roof-top macro base station. It demonstrates the validity of both measurement and computation evaluation methods for this base station situation.

The compliance boundary assessment determined the area around the base station antennas where the exposure limits are not exceeded, and the control boundary assessment confirmed the location of the physical access controls such as barriers and warning signs. The evaluation included on-site spatially averaged field strength measurement at the control boundary and a desktop computation to determine the compliance boundary. The maximum values were compared against the ICNIRP international safety guidelines.

An initial visual inspection at the site showed the potential for a significant RF field contribution from other RF sources. A wide frequency sweep established that the ambient contribution would not be significant and hence only the RF fields from the RBS under evaluation needed to be considered. Prior to the on-site field strength measurements, an initial estimate of the control boundary distance was calculated to be 13,2 m from the antennas for the general public limit and 3,2 m for the occupational exposure limit.

Spatially averaged field strength measurements were then performed on the roof-top at the selected control boundary distances of 13,2 m and 3,2 m from the antennas. The measurements demonstrated the actual field strength levels were well below the occupational and general public limits allowing for the maximum operating power. This verifies that conservative control boundaries have been selected.

A separate desktop evaluation using a commercial computation tool with ray tracing determined that the distance from the antenna to general public compliance boundary was less than 10 m, and less than 1 m to the occupational compliance boundary, along the maximum exposure radial under maximum operating power.

Full uncertainty analyses were performed for both evaluation methods indicating high confidence that actual exposure would be less than the ICNIRP limits at the specified control boundary distances. The best estimate assessment scheme was used for both the desktop evaluation and field strength measurement.

This case study illustrates:

- evaluation of RF field strength from cellular base station antennas with direct access to the antennas;
- comparison of computational evaluation and on-site measurement;
- identification of compliance boundaries on the roof-top.

Figure 4 shows the evaluation site, in Cape Town. It is an example of a roof-top site with direct access to the antennas, which in this example are flush mounted on building's exterior. The case study is available in full in Annex D.



Figure 4 – Roof-top case study with direct access to antennas

4.6 Roof-top case study with large antennas and no direct access

The purpose of this case study is to evaluate the RF exposure levels in accessible areas on a building roof-top in Tokyo.

The equipment under test (EUT) was categorised as a Complex RBS due to the multiple frequency bands and technologies supported.

The evaluation involved frequency selective measurements of the radio base station control channels and extrapolation for maximum operating power. The maximum values were compared against the ICNIRP guideline.

The assessment showed that the total exposure level from the mobile base station antennas in accessible areas of the building roof-top was lower than the specified limits at maximum traffic, as well as at the available maximum transmitting power.

This evaluation was performed using a target uncertainty assessment scheme. If the target uncertainty is met, then the measured value is compared directly with the limit. If the target uncertainty is not met, then the comparator is the measured value increased to the upper 95 % confidence level. In this case study the target uncertainty was met.

This case study illustrates:

- RF exposure levels in accessible areas of a building roof-top from a complex base station;
- an assessment using a target uncertainty scheme;
- comparison of computational evaluation and on-site measurements;
- frequency selective spatial average measurements;
- evaluation of nearby radio and broadcast signal levels.

Figure 5 shows the roof-top in Isehara City, Japan used for this case study.

The case study is available in full in Annex E.



Figure 5 – Roof-top case study with large antennas and no direct access

4.7 Circular cylindrical compliance boundary determination case study with large antennas and no direct access

The purpose of this survey was to determine a radio frequency (RF) exposure compliance boundary (occupational and general public) for a specific combined Long Term Evolution (LTE) and GSM site in Stockholm.

The compliance boundaries were evaluated against the international safety guidelines known as the ICNIRP (International Commission on Non-Ionizing Radiation Protection) guidelines. The assessment was made in terms of the Specific Absorption Rate (SAR) for adult RF exposure using formulae for SAR estimation.

The compliance boundary for occupational exposure using the cylinder SAR model was assessed to be 0,5 m in diameter and 1,4 m height in front of the antenna.

The compliance boundary for general public exposure using the cylinder SAR model was assessed to be 1,7 m in diameter and 1,5m height in front of the antenna.

Results are presented for this case study using the upper 95 % CI assessment scheme. The SAR exposure level is reported and the uncertainty value stated.

This case study illustrates:

- a compliance boundary assessment for a combined GSM and LTE base station;
- a compliance boundary assessment using a SAR model.

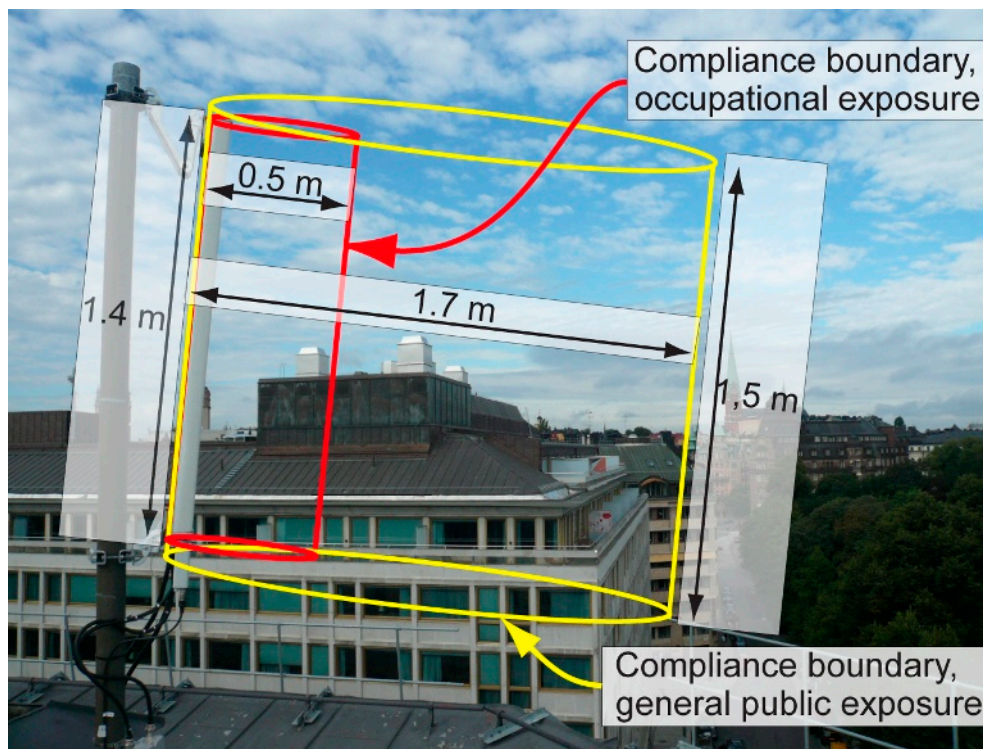


Figure 6 – Cylindrical compliance boundary determination for dual band antenna on building

Figure 6 shows a radio base station antenna on a roof-top in Stockholm which was the subject of this evaluation involving GSM and LTE systems.

The case study is available in full in Annex F.

4.8 Tower case study in parkland

This case study evaluates the RF exposure levels in a playing field in close proximity to a radio tower with broadcast and cellular base station radio services.

The purpose of the survey was to determine observed field strength values along footpaths and on a sports field adjacent to a base station site at a church green in Essex UK. The maximum values would then be compared against international safety guidelines known as ICNIRP (International Commission on Non-Ionizing Radiation Protection) guidelines.

The equipment under test (EUT) was categorised as a Complex RBS due to the multiple frequency bands and technologies supported.

Unknown transmitters on site meant that the assessment was conducted by on-site measurement. All values recorded were well below ICNIRP general public reference levels. The maximum values recorded corresponded to 0,295 % of the ICNIRP reference level.

This evaluation was conducted using the best estimate assessment scheme where the measured levels are reported and uncertainty stated.

This case study illustrates:

- RF exposure levels on a playing field in close proximity to a radio tower;
- an RF exposure assessment where site configuration details for some of the radio services are unknown.



Figure 7 – Tower case study in parkland

The location for the evaluation site was Essex, in the United Kingdom. The structure and antennas are shown in Figure 7 (left) and the evaluation location, which included a sporting field, in Figure 7 (right).

The case study is available in full in Annex G.

4.9 Multiple towers case study at sports venue

The purpose of this case study was to determine the maximum field strength contribution from a new cellular base station to give reassurance of the low levels where the public have regular access. This base station is one of several located on lighting towers around a sports ground.

The equipment under test (EUT) was categorised as a Complex RBS. Ambient fields, including those from the other RBS operating at the sports ground, were not the subject of this particular investigation. Only the dominant sector pointing into the oval was considered. The assessment involved determining the location on the sports ground with the maximum exposure ratio from the RBS under evaluation. This was determined first using a conservative desktop computation and then verified by on-site frequency selective field strength measurements. The results were assessed against the General Public reference levels defined in Australian Radiation Protection Standard (based on the ICNIRP Guidelines).

The modelled maximum cumulative RF EME levels from the RBS were 0,5 % of the general public exposure limit. The measured maximum cumulative RF EME levels from the RBS were 0,04% of the general public exposure limit. The measurement result verifies the conservative outcome of the desktop modelling.

The frequency selective measurements were performed using a hand-held measuring instrument with integrated isotropic probe. Separate measurements were made of control channels and across the operating band for each of the technologies supported by the RBS. Measurements were performed at the computed max field location. Additional measurements were made at locations around the predicted location of the maximum field strength in order to confirm the validity of the computation. The maximum and time averaged field strengths were measured at three heights above the ground where the power output is known.

The “best estimate” assessment scheme has been applied and the calculated and measured levels reported, including the extrapolation for maximum base station power configuration.

This case study illustrates:

- RF exposure levels on a sports ground from base station antennas on a light tower;
- a comparison of measured and calculated RF exposure.

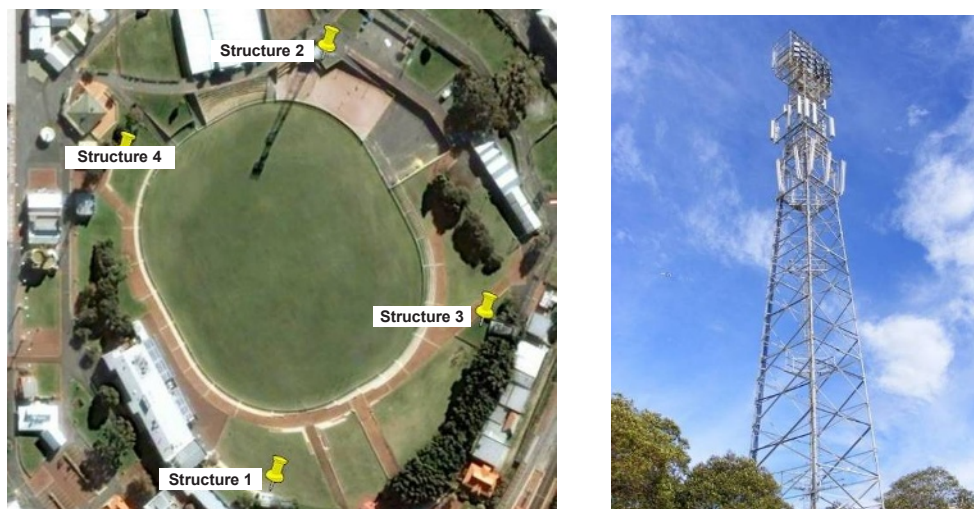


Figure 8 – Multiple towers case study at sports venue

The subject of this evaluation is shown in Figure 8 (left), a sporting ground/showground at Perth, Australia. The site consisted of multiple radio base stations located on separate lighting poles, see Figure 8 (right). The case study is available in full in Annex H.

4.10 In-building base station case study

This case study considers the verification of RF exposure compliance in publically accessible areas for an indoor distributed antenna system. The system is comprised of distributed antennas mounted on the ceiling of each floor of an occupied office building.

The equipment under test (EUT) is the individual radiating antennas on each floor in a low power distributed antenna system. There are no other radiating RF sources at the site under evaluation. This assessment was performed by the Electromagnetic Environment Lab of China Mobile Group Design Institute as part of their internal auditing program of mobile communication base stations. The results of the evaluations are compared against the reference limits of National standard 8702-88 of the People's Republic of China (GB 8702-88).

This assessment was performed using computational evaluation and on-site broadband field strength measurement. The final results were based on the field strength measurement.

The maximum measured RF field strength, found on floor 14, was $13,83 \mu\text{W}/\text{cm}^2$ and the expanded uncertainty was determined to be 2,26 dB. The “best estimate” assessment scheme was then applied to compare the measured RF field strength directly with the reference limit. This demonstrated that the RF field strength is considerably less than the relevant reference limits. The distributed antenna system installed in this building is therefore in compliance with National standard 8702-88 of the People's Republic of China (GB 8702-88).

This case study illustrates:

- RF exposure levels inside an office building in close proximity to small antennas which are part of a distributed antenna system;
- a comparison of field strength measurements and computational assessment.



Figure 9 – Office building IBC case study

The subject of the evaluation, shown in Figure 9, was a distributed antenna system installed in a Beijing office. Figure 9 consists of a wide shot of the antenna in-situ and shows a close-up (inset) of an in-building antenna. The case study is available in full in Annex I.

Annex A (informative)

Micro cell case study

This annex contains the Micro cell case study referred to in 4.2. This evaluation report is presented as issued by Ericsson AB and retains its original structure, formatting, layout and numbering. The standard referred to in the report is IEC 62232.



Ericsson AB

Evaluation Report

Building Stockholm, Sweden

Björn Hansson
10/4/2008

Evaluation Report Template

Date of Report: 10th April, 2008	
Title: Micro cell Evaluation Stockholm Sweden	
Site Location: Building, Stockholm, Sweden	
Site Coordinates (at Antenna): removed	
Google Earth Hyperlink: removed	
Evaluation laboratory: Ericsson EMF Research Laboratory Ericsson AB SE-164 80 Stockholm Sweden	Company/Client: Lars-Eric Larsson EMF Management, System Development & Strategy TeliaSonera Lagergrens gata 7, SE- 652 26 Karlstad, Sweden
Evaluation performed by: Björn Hansson	Date of Evaluation: 2008-04-02 to 2008-04-09
Identification number of original report: EAB-08:027926 Uen	
Assessor:  Björn Hansson Research Engineer bjorn.hansson@ericsson.com Tel: +46 8 404 22 02	Quality Assurance:  Martin Siegbahn Senior Research Engineer martin.siegbahn@ericsson.com Tel: +46 10 717 08 11

1. Executive Summary

The purpose of this case study was to assess the RF exposure compliance boundaries from a particular micro cell installation on a building wall to determine whether they would extend to a nearby awning. Both the Basic Restrictions and Reference Levels were assessed to determine the minimum distance from the antenna to the compliance boundary.

The maximum values were compared against international safety guidelines known as ICNIRP (International Commission on Non-Ionizing Radiation Protection) guidelines. The assessment establishes compliance against the Basic Restrictions known as Specific Absorption Rate and the field strength reference levels. SAR testing was performed in a laboratory and frequency selective field measurements were performed on site.

The Equipment Under Test (EUT) was categorised as a Simple RBS due to the single technology and single antenna of the micro cell. Nearby base stations, known as secondary sources, had negligible impact on both SAR and field strength evaluations.

The measured SAR and field strength levels were extrapolated to assess the maximum power configuration for the site.

The “best estimate” uncertainty model has been applied and the measured levels are reported including the extrapolation for maximum base station power configuration. The uncertainty is stated for all assessment methods used.

The compliance boundary distance for general public exposure using the on-site field strength measurement was 0.8 m, and 0.08 m using the SAR evaluation.

Both the SAR evaluation and the on-site field strength measurements confirm that the general public exposure compliance boundary from the micro cell antenna does not extend onto the building awning, therefore access is permitted on the awning.

2. Evaluation Overview

2.1. Site operator information

The test results presented in this report define compliance boundaries for the micro cell base station antenna flush mounted on the wall. The details of the operator are shown below in Table 2.1.1.

Table 2.1.1: Micro cell operator technology information- primary source

Product	Ericsson RBS 2202
Operator	TeliaSonera
Transmitting antenna	Kathrein 741 316
Antenna location	Electrum building (Isafjordsgatan 26, SE- 164 40 Stockholm, Sweden)
Technologies	GSM 900, GSM 1800
Antenna dimensions (h/w/d)	0.66 / 0.26 / 0.12 m
Antenna mounting	4 m above ground on building wall
Typical output power (as specified by operator)	GSM 900: 34 dBm GSM 1800: 31.5 dBm

Maximum output power (as specified by operator)	GSM 900: 37 dBm GSM 1800: 34.5 dBm
Broadcast channels	GSM 900: ch. 34 (941.8 MHz) GSM 1800: ch. 632 (1829.2 MHz)

The TeliaSonera micro cell antenna is located in the vicinity of four other base station antennas, known as secondary sources. The secondary sources are described in Table 2.1.2 below.

Table 2.1.2: Secondary sources information

Products	Ericsson RBS 2202 (GSM 900/1800) (Telenor) Nokia Supreme (WCDMA 2100) (Telenor) Ericsson RBS3202 (WCDMA 2100) (3)
Operators	Telenor (three color matched antennas) 3 (antenna above the colour matched antennas)
Transmitting antennas	Kathrein 739 494, 742 212 and 739633 (Telenor) Kathrein 742 215 (3)
Antenna location	Electrum building (Kistagången 16, SE- 164 80 Stockholm, Sweden)
Technologies	GSM 900, GSM 1800, WCDMA 2100
Antenna mounting	Approx. 2 m above primary source (Telenor) 3 to 4 m above primary source (3)
Broadcast / Pilot channels	GSM 900: ch. 114 (912.8 MHz) (Telenor) GSM 1800: ch. 800 (1767.8 MHz) (Telenor) WCDMA 2100: ch. 10588 (2117.6 MHz) (Telenor) WCDMA 2100: ch. 10687 (2137.4 MHz) (3)

2.2. Site environment

The micro cell antenna is flush mounted on a building wall approximately 4 m above the footpath. As shown in Figure 2.2 there are macro antennas (some colour matched) flush mounted on a building wall approximately 6 m and higher, above the footpath. The awning is the metallic gold coloured structure below the micro cell antenna.



Figure 2.2 Photograph of micro cell antenna

2.3. Exposure safety limits

ICNIRP is a body of independent scientific experts who investigate the possible adverse effects of exposure to non-ionizing radiation. ICNIRP, in conjunction with the World Health Organization (WHO), developed the ICNIRP Exposure Guidelines.

This assessment compares results against the ICNIRP Guidelines for Time Varying Electric and Magnetic Fields for frequencies up to 10 GHz for both Basic Restrictions (SAR) and Reference Levels.

ICNIRP guidelines contain two levels, one for occupational exposure the other for the general public. The purpose of this evaluation was to determine the distance from the antenna to the occupational and general public boundaries.

3. Evaluation Plan (Annex A of standard)

3.1. Pre-evaluation review

The purpose of the pre evaluation review is to develop an estimate of the expected field strength (and SAR) and consequently an appropriate selection of evaluation methods for a given evaluation purpose.

3.1.1. Determine evaluation purpose

The evaluation purposes were to establish boundary against limit value and to provide information of typical value for RF exposure.

3.1.2. Determine equipment under test (EUT) category

The equipment under test is defined as a simple RBS.

3.1.3. Determine physical parameters

Table 3.1.1 — Physical parameters

Antenna type number	Kathrein 741 316
Horizontal HPBW	65° (870-960 MHz) and 60° (1710-1800 MHz)
Vertical HPBW	28° (870-960 MHz) and 19° (1710-1800 MHz)
Directivity	12.5 dBi (870-960 MHz) and 13 dBi (1710-1880 MHz)
Orientation	Back of antenna mounted on wall, 4 m above ground
Broadcast channels	GSM 900: ch 34 (941.8 MHz), GSM 1800: ch 632 (1829.2 MHz)
Maximum transmit power	37 dBm (GSM 900) and 34.5 dBm (GSM 1800)
Typical transmit power	34 dBm (GSM 900) and 31.5 dBm (GSM 1800)

3.1.4. Decide if ambient fields are to be considered

No. Since the requirement is to establish only exposure from the RBS RF fields.

3.1.5. Establish the evaluation locations required

Source regions I and II. Environment region 0.

Table 3.1.2 — Mapping of evaluation locations on the source-environment plane

Source – Environment Region		
I-M	II-M	III-M
I-1	II-1	III-1
I-0 X	II-0 X	III-0

Map the evaluation locations onto a source-environment plane with the source regions on the X axis and the complexities of the environment (scatterer/absorber) on the Y axis.

3.1.6. Estimate the field at the evaluation point

The spherical formula in Clause 6.3.2 predicts by assuming typical transmit power at both GSM 900 and GSM 1800 a total electric field strength at 1 m from the antenna (front direction) of approximately 47 V/m (approximately 37 V/m for GSM 900 and 29 V/m for GSM 1800).

3.1.7. Establish which parameters are to be evaluated

Region I: SAR and E & H

Region II: E or H

3.2. Select evaluation method

The site assessment method chosen for this evaluation was both on-site frequency selective field measurements and laboratory testing of SAR. The decision to conduct the assessment by measurement was made by the assessor in conjunction with the client's request to determine the minimum distance from the antenna to the compliance boundary using SAR and field strength.

All field strength measurement results given in this report are best estimate values, i.e. the probability is 50 % that the true value is either above or below the given value. The laboratory SAR measurements establish a conservative value provided the expanded uncertainty of the SAR measurement is below the constraint in IEC 62209-2 – this was achieved in this case study.

3.3. Complete the evaluation plan

Develop check sheet to be used on site

Table 3.3.1 — SAR measurement check sheet

Make sure that the equipment and instruments to be used are calibrated	☐
Measure dielectric properties of liquid	☐
Perform system performance check	☐
Set the EUT to transmit at the maximum output power level, or measure the forward power and the reflected power.	☐
Position EUT so that it touches the phantom shell and the radiating parts are centred with respect to the phantom	☐
Make sure that the EUT is levelled	☐

Position the EUT for the desired separation between the reference point of the EUT and the liquid surface	☐
Make sure that the EUT is levelled	☐
Document instrumentation used	☐
Setup the measurement system: liquid parameters, EUT properties, probe, DAE and measurement areas are specified in the system configuration setting	☐
Perform reference measurement, area scan, zoom scan and power drift measurement	☐
Apply correction factor (a number between 1 and 2 depending on separation distance). See clause 7.3.4.	☐
Post process data if needed (e.g. scale to maximum power etc.)	☐

Table 3.3.4 —Field measurement check sheet

Make sure that the equipment and instruments to be used are calibrated	☐
Consider the safety of the public and the people conducting the measurements	☐
Document measurement area (address and location)	☐
Take photographs of the site	☐
Document date and time	☐
Make notes on weather conditions and human movement in the survey area	☐
Document instrumentation used	☐
Select measurement method based on Table 9 (clause 7.2.2)	☐
Consider the location of the source and the RF propagation path to evaluate the effect of the presence of the assessor's body and to minimize measurement errors	☐
Consider if other RF sources may affect the evaluation	☐
Select measurement locations	☐
Consider if the reading may be instrument noise	☐
Consider spatial averaging (see Table 10, clause 7.2.5.3)	☐
Perform measurements and document results in result sheet	☐

3.4. General methodology- SAR (Clause 6.2.3 of standard)

The measurement of Specific Absorption Rate requires highly specialised equipment and is performed in a laboratory and not *in situ*. The laboratory measurements were performed at the Ericsson EMF Research Laboratory Ericsson AB, SE-164 80 Stockholm Sweden. A miniature electric field probe positioned by a software-controlled high precision robot was used to measure the internal electric field of a liquid-filled phantom representing the human body. The electric field data was processed to determine the SAR distribution inside the phantom and the maximum mass-averaged SAR.

The SAR was measured without the antenna radome at the BCCH frequency of each frequency band (channel 34 for GSM 900 and channel 632 for GSM 1800). The antenna was initially positioned horizontally beneath the phantom with the front of the antenna facing upwards. Measurements were made as function of the phantom-antenna separation, with an increment of 25 mm. The phantom-antenna separation was measured between the antenna elements and the liquid surface in the phantom (phantom shell thickness: 6.9 mm $\pm$ 0.2 mm). The measurements were then repeated for the back, side, and top configurations (facing the phantom). The phantom-antenna separation was increased until the sum of the localized SAR_{10g} values (normalized to the maximum output power specified by operator) obtained for 900 and 1800 MHz fell below the basic restrictions for 10g averaged SAR.

A signal generator was used together with an amplifier and a power meter to control the CW signal fed into the antenna.

The SAR measurements were performed using a flat phantom from APREL Laboratories together with the DASY4 professional near-field scanner.

The base station antenna is located in the vicinity of four other base station antennas, known as secondary sources, but the SAR contribution from these antennas was considered to be negligible (see Section 4.2).

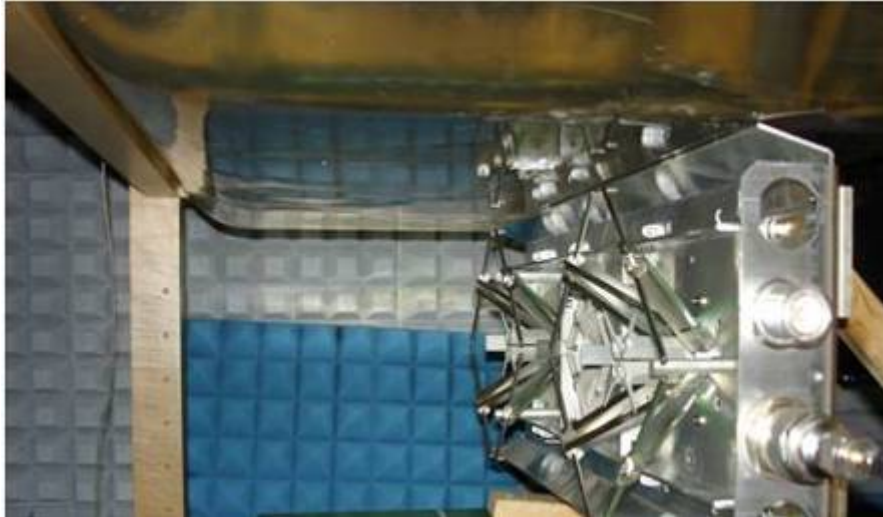


Figure 3.4 SAR testing view from below showing the antenna without radome positioned with one of its sides facing the phantom shell.

Figure 3.4 above shows a view from below of the antenna under test with its radome removed. The flat panel phantom can be seen at the top of the photo. In the background the blue and grey patterned RF absorbing (anechoic) material can be seen.

3.5. General methodology- on-site field strength measurement (Clause 6.2.2 of standard)

The reference level field evaluation is an on-site field strength measurement performed with portable handheld test equipment. As shown in Figure 3.5 below the test results presented in this report define compliance boundaries for the Kathrein 741 316 base station antenna situated on the Electrum building wall communicating with simultaneous downlink transmission in the GSM 900 and GSM 1800 bands. Frequency selective electric field strength measurements were performed at the GSM 900 DL channel 34 (941.8 MHz) and GSM 1800 DL channel 632 (1829.2 MHz) using a SRM-3000 (Selective Radiation Meter) by Narda Safety Test Solutions.



Figure 3.5 On-site field strength evaluation.

The measurement results for the different bands were extrapolated to maximum traffic for this specific base station antenna (as specified by operator) and the exposure ratios for each band were calculated and summed. Compliance boundaries for the base station antenna were calculated based on the resulting exposure ratio.

The following steps were performed during the assessments:

- i. Single E-field measurement at 0.2 m distance from the antenna over the whole frequency range (75 MHz-3 GHz), with a resolution bandwidth of 5 MHz using the “Safety Evaluation” mode of the SRM-3000, in order to identify sources of interest.
- ii. Single E-field measurements at 0.2 m distance from the antenna over the whole GSM 900 DL band, and the GSM 1800 DL band, subsequently, in order to identify the broadcast channels for each band.
- iii. Subsequent E-field measurements at the broadcast channels for GSM 900 DL and GSM 1800 DL at distances from the front of the antenna ranging from 0.1 m to 1.9 m, with an increment of 0.1 m.
- iv. Subsequent E-field measurements at the broadcast channels for GSM 900 DL and GSM 1800 DL at distances from the side of the antenna ranging from 0.06¹ m to 0.3 m.
- v. Subsequent E-field measurements at the broadcast channels for GSM 900 DL and GSM 1800 DL at distances from the bottom of the antenna ranging from 0.06 m to 0.1 m.
- vi. Broadband H-field measurements at distances from the front of the antenna ranging from 0.1 to 0.7 m, and at distances from the bottom and the side of the antenna corresponding to the E-field measurements described above.
- vii. Additional measurements of secondary sources were conducted on the broadcast and common pilot channels of the antennas in the vicinity.

¹ The distance from the antenna was measured between the centre of the SRM-3000 probe to the radome of the Kathrein 741 316 antenna. 0.06 m was the closest possible distance to measure (the antennas were touching each other).

- viii. All nearfield measurements were conducted using continuous scanning for peak level in front of antenna; spatial averaging was not used in this evaluation.

4. Results (Clause 8 of standard)

4.1. Results summary- SAR

This results clause contains a summary of the SAR results detailing the compliance boundary distances from the antenna. The compliance boundary for this site was determined by comparing the sum of the SAR values for the GSM 900 and the GSM 1800 with the international exposure limits. The results are given as the distance to the antenna radome (the measurements were performed without the radome) and are presented below in Table 4.1. The distance from the antenna elements to the radome for the antenna was 0.03 m.

Table 4.1 — Compliance distances for general public (GP) and occupational (O) exposure for the specified configurations.

Configuration		Compliance distance ² (m)	
Frequency band / channel	Antenna orientation	GP	O
GSM 900 / 34 + GSM 1800 / 632	Front	0.08	0
GSM 900 / 34 + GSM 1800 / 632	Back	0	0
GSM 900 / 34 + GSM 1800 / 632	Top/Bottom	0	0
GSM 900 / 34 + GSM 1800 / 632	Sides	0	0

For more information see Appendix C.

4.2. Results summary- On-site field strength measurement

The compliance boundary for this base station antenna was determined by extrapolating the raw data to maximum traffic using an extrapolation factor of 2 (Two TRX:s for both GSM 900 and GSM 1800) for both downlink bands. In the near field region of the antenna both E-field and H-field measurement results were considered. The extrapolated field values were used to compute exposure ratios by applying ICNIRP's reference levels. The exposure ratios for each frequency band and measurement point were added resulting in total exposure ratios for each measurement point. Based on the total exposure ratios compliance distances were determined as shown in Table 4.2.

Table 4.2 — Compliance distances for general public (GP) and occupational (O) exposure for the specified configurations

Configuration		Compliance distance ³ (m)	
Frequency band / channel	Antenna orientation	GP	O
GSM 900 / 34 + GSM 1800 / 632	Front	0.8	0.6 ⁴
GSM 900 / 34 + GSM 1800 / 632	Back ⁵	N/A	N/A
GSM 900 / 34 + GSM 1800 / 632	Top/Bottom	<0.06	<0.06
GSM 900 / 34 + GSM 1800 / 632	Sides	0.1	<0.06

Additional measurements on the broadcast channels and common pilot channels of the antennas in the vicinity were conducted. The measurement results were extrapolated to maximum traffic and the

² This distance is defined as the minimum distance to the antenna, i.e. to the antenna radome.

³ This distance is defined as the minimum distance to the antenna, i.e. to the antenna radome.

⁴ This distance is based on broadband H-field measurements and is therefore an overestimation of the compliance distance.

⁵ No measurements were performed behind the antenna since the antenna was mounted directly against the wall.

contribution to the exposure ratio was computed. The contribution to the exposure ratio was found to be in the order 0.2-0.4 %. The compliance distances are therefore not influenced by these secondary sources.

For more information see Appendix D.

4.3. Assessment scheme – interpretation of results

The “best estimate” assessment scheme has been applied and the measured levels are reported including the extrapolation for maximum base station power configuration. The uncertainty is stated for all assessment methods used.

4.4. Uncertainty

The uncertainty has been assessed for each of the methods used and the obtained values are given in Table 4.3. A detailed uncertainty evaluation is given in Appendix A.

Table 4.3 — Expanded uncertainty for the methods used.

Assessment method	Expanded uncertainty (k=2)	Correction factor
SAR measurement	21.4 %	0 %
Frequency selective field measurement	3.5 dB	0.23 dB
Broadband field measurement	4.3 dB	0 dB

4.5. Further information

Further information on the test instrumentation including equipment types and calibration details can be found in Appendix B

Appendix E includes a copy of the SAR system performance check.

5. Conclusions

The purpose of this case study was to assess the RF exposure boundaries from the micro cell mentioned above to determine whether they would extend to a nearby awning. Both the SAR evaluation and the on-site field strength measurements confirm that the general public exposure compliance boundary from the micro cell antenna does not extend onto the building awning, therefore access is permitted on the awning.

The SAR tests show that the micro cell base station parameters of the Stockholm building in Sweden operating simultaneously at GSM900 and GSM1800 is in compliance with the general public and occupational RF exposure limits at a minimum distance from the antenna of 0.08 m / 0 m in the front direction, respectively.

Similarly, the on-site field strength tests show that the micro cell base station is in compliance with the general public and occupational RF exposure limits at a distance from the antenna of 0.8 m / 0.6 m in the front direction, 0.1 m / <0.06 m in the side directions, and at a distance of <0.06 m / <0.06 m from the top and bottom of the antenna, respectively.

Nearby base stations, known as secondary sources, had negligible impact on both SAR and on-site field strength evaluations.

Appendix A (Evaluation Report) - Uncertainty Analysis

(Clauses 6.2.2.6, 6.2.3.5, 7, and Annex O)

A.1 Uncertainty analysis -SAR

Below in Table A.1 is the uncertainty evaluation of SAR measurement system DASY4 according to IEC 62209-2.

Table A.1. Uncertainty evaluation SAR

Uncertainty Component	Clause in IEEE 1528	Uncer. (%)	Prob Dist.	Div.	C _{i,10g}	Std. Uncer. (10g) (%)
Measurement System						
Probe Calibration	E2.1	±5.9	N	1	1	±5.9
Axial Isotropy	E2.2	±4.7	R	√3	0.7	±1.9
Spherical Isotropy	E2.2	±9.6	R	√3	0.7	±3.9
Boundary Effect	E2.3	±1.0	R	√3	1	±0.6
Linearity	E2.4	±4.7	R	√3	1	±2.7
System Detection Limits	E2.5	±1.0	R	√3	1	±0.6
Readout electronics	E2.6	±0.3	N	1	1	±0.3
Response time	E2.7	±0.8	R	√3	1	±0.5
Integration time	E2.8	±2.6	R	√3	1	±1.5
RF Ambient Noise	E6.1	±3.0	R	√3	1	±1.7
RF Ambient Reflections	E6.1	±3.0	R	√3	1	±1.7
Probe Positioner	E6.2	±0.4	R	√3	1	±0.2
Probe Positioning	E6.3	±2.9	R	√3	1	±1.7
Max. SAR Evaluation	E5	±1.0	R	√3	1	±0.6
Measurement System Uncertainty						±8.6
Test Sample Related						
Device positioning	E4.2	±2.9	N	1	1	±2.9
Device holder uncertainty	E4.1	±3.6	N	1	1	±3.6
Power drift	6.6.3	±5.0	R	√3	1	±2.9
Test Sample Related Uncertainty						±5.5

Phantom and Tissue Parameters						
Phantom uncertainty	E3.1	±4.0	R	√3	1	±2.3
Liquid conductivity (meas uncertainty)	E3.3	±2.5	N	1	0.43	±1.1
Liquid conductivity (target)	E3.2	±5.0	R	√3	0.43	±1.2
Liquid Permittivity (meas uncertainty)	E3.3	±2.5	N	1	0.49	±1.2
Liquid Permittivity (target)	E3.2	±5.0	R	√3	0.49	±1.4
Phantom and Tissue Parameters Uncertainty						±3.4
Combined standard uncertainty						±10.7
Extended standard uncertainty (k=2)						±21.4

A.2 Uncertainty analysis – on-site field strength

Below in Tables A.2 and A.3 is the uncertainty evaluation for the frequency selective and the broadband field measurements, respectively.

Table A.2 — Uncertainty evaluation for the frequency selective field measurements (SRM-3000).

Source of uncertainty (influence quantity)	Description	Unit	prob. distrib. type	semi span a	divisor d	sens. coeff. c	Correction factor t	stand. uncert. $u = a/d$	C^2u^2
Measurement equipment									
Combined instrument uncertainty ⁶	As specified by instrument manufacturer ⁷	dB	normal	2.85	2	1	+0.23	1.425	2.03
Methodology									
Probe position in high field gradients	A search procedure was used to find the maximum reading at a certain distance	dB	rect	0	1.73	1	0	0	0
Field reflections from measurer's body during measurement	Influence of Probe > 1m away from body of the measurer (use CENELEC Annex G results from	dB	rect	1.5	1.73	1	0	0.87	0.750

⁶ The following components are included in the combined instrument uncertainty: calibration of the basic unit, antenna and cable, mismatches in the connections between the antenna and cable and between the cable and the basic unit, and the anisotropy / ellipticity of the measuring antenna.

⁷ The data was obtained from the Narda STS application note "Accounting for measurement uncertainty in the SRM-3000". A normal probability distribution was assumed.

Source of uncertainty (influence quantity)	Description	Unit	prob. distrib. type	semi span a	divisor d	sens. coeff. c	Correction factor t	stand. uncert. $u = a/d$	$C^2 u^2$
	simulation (worst case) in cellular band)								
Meter reading error of fluctuating signals	No analogue meter reading was made	dB	triang	0	2.45	1	0	0.00	0.000
Source and environment									
Variation in the power of the RF source from the nominal level	Ericsson specifies an output power tolerance of +/- 1 dB	dB	rect	1	1.73	1	0	0.58	0.333
Field reflections from movable large objects near the source during measurement	N/A	dB	rect	0	1.73	1	0	0	0
RF propagation & environmental clutter loss (for low level environmental measurements)	Not applicable - high level environment in direct line of sight to source	dB	triang	0	2.45	1	0	0.00	0.000
Combined correction factor, $t_c = \sum_{i=1}^N t_i$									0.23
Combined standard uncertainty, $u_c = \sqrt{\sum_{i=1}^N (c_i^2 u_i^2)}$									1.76
Coverage factor for 95% CI, k									1.96
Expanded Uncertainty, $U = k \times u_c$									3.5

Table A.3 — Uncertainty evaluation for the broadband field measurements (EMR-300).

Source of uncertainty (influence quantity)	Description	unit	prob. distrib. type	semi span a	divisor d	sens. coeff. c	Correction factor t	stand. uncert. $u = a/d$	$C^2 u^2$
Measurement equipment									
Read-out unit calibration	As specified by instrument manufacturer	dB	normal	0.05	1	1	0	0.05	0.0025
Absolute calibration	As specified by instrument manufacturer	dB	rect	1	1.73	1	0	0.577	0.33
Isotropy, axial	As specified	dB	rect	1	1.73	1	0	0.577	0.33

Source of uncertainty (influence quantity)	Description	unit	prob. distrib. type	semi span a	divisor d	sens. coeff. c	Correction factor t	stand. uncert. $u = a/d$	$C^2 u^2$
	by instrument manufacturer								
Linearity	As specified by instrument manufacturer	dB	normal	1	1	1	0	1	1.0
Frequency response	As specified by instrument manufacturer	dB	rect	2.4	1.73	1	0	1.387	1.9
Amplitude modulation, GSM one slot	As specified by instrument manufacturer	dB	rect	0.8	1.73	1	0	0.462	0.21
Temperature	As specified by instrument manufacturer	dB	rect	0.2	1.73	1	0	0.116	0.013
Methodology									
Probe position in high field gradients	A search procedure was used to find the maximum reading at a certain distance	dB	Rect	0	1.73	1	0	0	0
Field reflections from measurer's body during measurement	Influence of Probe > 1m away from body of the measurer (use CENELEC Annex G results from simulation (worst case) in cellular band)	dB	rect	1.5	1.73	1	0	0.87	0.750
Meter reading error of fluctuating signals	A peak-hold function was used.	dB	Triang	0	2.45	1	0	0.00	0.000
Source and environment									
Variation in the power of the RF source from the nominal level	Ericsson specifies an output power tolerance of +/- 1 dB	dB	Rect	1	1.73	1	0	0.58	0.333
Field reflections from movable large objects near the source during measurement	N/A	dB	Rect	0	1.73	1	0	0	0

Source of uncertainty (influence quantity)	Description	unit	prob. distrib. type	semi span a	divisor d	sens. coeff. c	Correction factor t	stand. uncert. $u = a/d$	$C^2 u^2$
RF propagation & environmental clutter loss (for low level environmental measurements)	Not applicable - high level environment in direct line of sight to source	dB	Triang	0	2.45	1	0	0.00	0.000
Combined correction factor, $t_c = \sum_{i=1}^N t_i$									0
Combined standard uncertainty, $u_c = \sqrt{\sum_{i=1}^N (c_i^2 u_i^2)}$									2.21
Coverage factor for 95% CI, k									1.96
Expanded Uncertainty, $U = k \times u_c$									4.3

Appendix B (Evaluation Report) – Equipment List

B.1 Equipment list -SAR

The SAR measurements were performed using a flat phantom from APREL Laboratories together with the DASY4 professional near-field scanner (software version 4.6) by Schmid & Partner Engineering AG. The total SAR assessment uncertainty ($k=1$) of the system is $\pm 10.7\%$ for 10g SAR assessments and the corresponding expanded uncertainty ($k=1.96$) is $\pm 21.4\%$. The equipment list and calibration parameters are given below in Tables B.1 and B.2.

Table B.1. SAR test equipment.

Description	Asset number	Calibration due date
DASY4 DAE3	S/N 304	08/10/15
E-field probe, ES3DV3	S/N 3155	09/03/17
Dipole validation kit, D900V2	S/N 1d039	NA
Dipole validation kit, D1800V2	S/N 203	NA
Universal flat phantom	S/N 513C-145-5	NA

Table B.2. Additional equipment

Description	Asset number	Calibration due date
Dielectric probe kit, HP 85070C	S/N US99360060	NA
Network analyser, HP 8752C	S/N 3410A03732	08/10/18
Power meter, R&S NRVS	S/N 848888/052	08/06/08
Power sensor, R&S NRV-Z5	S/N 849895/030	08/05/08
Thermometer, EBRO TFX-392SKWT	S/N 10130918	08/10/22
R&S SMB-B106 signal generator	S/N 100166	09/08/27

B.2 SAR- electrical parameters of the tissue simulating liquid

The parameters of the tissue simulating liquid were measured with the dielectric probe kit prior to the SAR measurement and the results are shown in Table B.3 below. IEC 62209 specifies reference values which have been used to verify the liquid measurements.

The measured values were within 5% of the reference values and the mass density of the liquid entered into the DASY4 program was 1000 kg/m^3 . The depth of the head tissue liquid in the phantom was $100 \text{ mm} \pm 5\%$.

Table B.3. Measured and specified parameter values for the tissue simulating liquid.

Frequency (MHz)	Measured/Specified	ϵ_r	σ (S/m)	Liquid Temp (°C)
900	Measured values	39.5	0.94	22.0
	Specified values	41.5	0.97	--
	Difference (%)	-4.8	-3.1	--
1800	Measured values ⁸	38.0 to 38.5	1.39 to 1.41	21.2 to 22.7
	Specified values	40.0	1.40	--
	Difference (%)	-4.9 to -3.8	-0.7 to +0.7	--

B.3 SAR- System performance check

System performance checks of the SAR test system were conducted prior to the SAR measurements. This was done using the D900v2 and the D1800v2 dipole validation kits. The obtained results are presented in Table B.4 and the results are within $\pm 10\%$ of the calculated reference values as required in IEC 62209. The temperature of the test facility during the tests was in the range 20°C to 25°C .

Table B.4. Measured and specified SAR levels for the system performance check.

Frequency (MHz)	Measured/Reference	SAR 1g (W/kg)	SAR 10g (W/kg)	ϵ_r	σ (S/m)	Date
900	Measured	8.0	5.3	39.5	0.94	08/04/07
	Reference	8.2	5.5	41.5	0.97	--
	Difference (%)	-2.8	-2.9	-4.8	-3.1	--
1800	Measured	13.8	8.1	38.5	1.39	08/04/02
	Reference	13.9	8.1	40.0	1.40	--
	Difference (%)	-0.7	± 0	-3.8	-0.4	--

⁸ The liquid parameters were measured in the morning every day before the SAR measurements began. All values were within the specified range.

B.4 Equipment list - on-site field strength

The measurements were mainly performed using the frequency selective instrument SRM-3000 by Narda Safety Test Solutions equipped with an isotropic E-field antenna. Additional H-field measurements at close distances from the antenna were performed using an EMR-300 by Narda Safety Test Solutions equipped with an isotropic H-field antenna. The equipment list is given in Table B.5, and the instrument settings of the SRM-3000 are specified in Table B.6.

Table B.5 — On-site field measurement equipment.

Description	Serial number	Calibration due date
SRM-3000 main unit	A-0060	07/11/08
E-field probe for SRM-3000	G-0023	18/10/09
EMR-300 main unit	AB-0037	25/02/10
H-field probe for EMR-300	A-0081	27/02/10

Table B.6 — Instrument settings used for the SRM-3000.

Centre frequency	Mode	Span	Resolution bandwidth	Detector
941.8 MHz	Spectrum analyser	5 MHz	0.3 MHz	RMS
1829.2 MHz	Spectrum analyser	3 MHz	0.3 MHz	RMS

Appendix C (Evaluation Report) – Measurement Results SAR

Table C.1 shows the 10 g averaged SAR results for the EUT when tested at the downlink channels in each frequency band. In addition to measured SAR, values normalized to the maximum output powers specified by the operator are also given. All SAR values include a correction factor ranging from 1 to 2 depending on phantom-antenna separation.

Table C.1 — Measured SAR and normalized SAR.

Frequency (MHz)	EUT position	Distance to liquid surface (m)	Measured output power (dBm)	Max SAR _{10g} (W/kg)	
				Measured	Normalized to maximum ⁹ output power, 37 dBm
941.8	Front facing phantom	0.007	34.7	6.71	11.4
		0.032	33.9	2.06	4.2
		0.057	34.9	1.21	2.0
		0.082	35.5	0.78	1.1
		0.107	34.8	0.50	0.81
941.8	Top facing phantom	0.007	35.7	0.18	0.24
941.8	Back facing phantom	0.007	35.7	0.02	0.02
941.8	Side facing phantom	0.007	35.7	0.36	0.49
Frequency (MHz)	EUT position	Distance to liquid surface (m)	Measured output power (dBm)	Max SAR _{10g} (W/kg)	
				Measured	Normalized to maximum output power, 34.5 dBm
1829.2	Front facing phantom	0.007	39.1	14.9	5.2
		0.032	39.2	5.3	1.8
		0.057	39.6	4.5	1.4
		0.082	39.7	4.4	1.3
		0.107	39.4	3.4	1.1
1829.2	Top facing phantom	0.007	39.8	0.34	0.10
1829.2	Back facing phantom	0.007	39.8	0.13	0.04
1829.2	Side facing phantom	0.007	39.8	1.27	0.37

⁹ Maximum output power specified by operator

Appendix D (Evaluation Report) – Measurement results on-site field strength.

The measurements corresponding to the first two steps in Clause 3.5 were mainly performed in order to ensure that all other measurements were conducted at the correct frequencies using the correct instrument settings. The safety evaluation measurement described in step 1 of Clause 3.5 showed that all other sources than GSM 900 DL and GSM 1800 DL were negligible, and the measurements described in Clause 3.5 step 2 showed that the broadcast channel frequencies given by the operator were correct.

Figure D.1 shows measured maximum electric field strengths at the broadcast channel for GSM 900 DL (left) and GSM 1800 DL (right) as function of distance from the front of the antenna radome. All measurement values, obtained using the frequency selective instrument, have been corrected by adding 0.23 dB according to the uncertainty analysis in Table A.2.

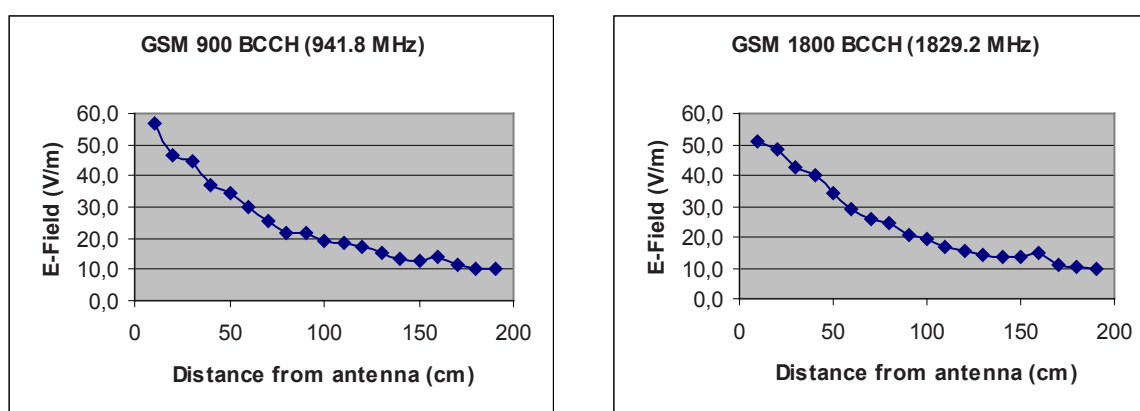


Figure D.1 — Measured electric field (V/m) at the broadcast channel of both GSM 900 and GSM 1800 for distances from the antenna front ranging from 0.1 m to 1.9 m.

Table D.1 gives measured maximum electric field strengths at the broadcast channel for GSM 900 DL (left) and GSM 1800 DL (right) as function of distance from the side of the antenna radome.

Table D.1 — Results from E-field measurements at distances ranging from 0.06 m to 0.3 m from the side of the antenna.

Distance from antenna (m)	E-field strength (V/m) GSM 900 BCCH (941.8 MHz)	E-field strength (V/m) GSM 1800 BCCH (1829.2 MHz)
0.06	27.1	22.9
0.1	20.8	18.8
0.2	15.6	9.5
0.3	9.7	5.5

Table D.2 gives the measured electric field strength at the broadcast channel for GSM 900 DL and GSM 1800 DL at distances of 0.06 m and 0.1 m from the antenna bottom.

Table D.2 — Results from E-field measurements at distances ranging from 0.06 m to 0.1 m from the bottom of the antenna.

Distance from antenna (m)	E-field strength (V/m) GSM 900 BCCH (941.8 MHz)	E-field strength (V/m) GSM 1800 BCCH (1829.2 MHz)
0.06	20.0	3.8
0.1	11.2	3.4

Table D.3 shows the broadband magnetic field strength results for close distances to the antenna.

Table D.3 — Results from H-field broadband measurements close to the antenna in different orientations.

Distance from antenna (m)	Orientation	H-field strength (A/m) (Broadband measurement)
0.1	Front	0.3
0.2	Front	0.28
0.3	Front	0.25
0.4	Front	0.22
0.5	Front	0.19
0.6	Front	0.17
0.7	Front	0.15
0.06	Side	0.1
0.1	Side	0.07
0.2	Side	0.041
0.3	Side	0.036
0.06	Bottom	0.057
0.1	Bottom	0.045

Appendix E: SAR test system performance check

E.1 System performance check at 1800 MHz conducted 08/04/02

Date/Time: 2008-04-02 17:34:33

-Communication System: CW; Frequency: 1800 MHz; Duty Cycle: 1:1

-Medium: Head 1800 MHz; $\sigma = 1.39$ mho/m; $\epsilon_r = 38.5$; $\rho = 1000$ kg/m³

DASY4 Configuration:

-Probe: ES3DV3 - SN3155; ConvF(5.1, 5.1, 5.1)

-Electronics: DAE3 Sn304

-Phantom: U-flat;

-Measurement SW: DASY4, V4.7 Build 53; Post processing SW: SEMCAD, V1.8 Build 172

d=20 mm, Prad = 244.3 mW/Area Scan 3 (121x61x1): Measurement grid: dx=10mm, dy=10mm
Maximum value of SAR (interpolated) = 3.72 mW/g

d=20 mm, Prad = 244.3 mW/Zoom Scan (5x5x7)/Cube 0: Measurement grid: dx=8mm, dy=8mm, dz=5mm

Reference Value = 52.2 V/m; Power Drift = -0.051 dB

Peak SAR (extrapolated) = 5.55 W/kg

SAR(1 g) = 3.38 mW/g; SAR(10 g) = 1.98 mW/g

Maximum value of SAR (measured) = 3.70 mW/g

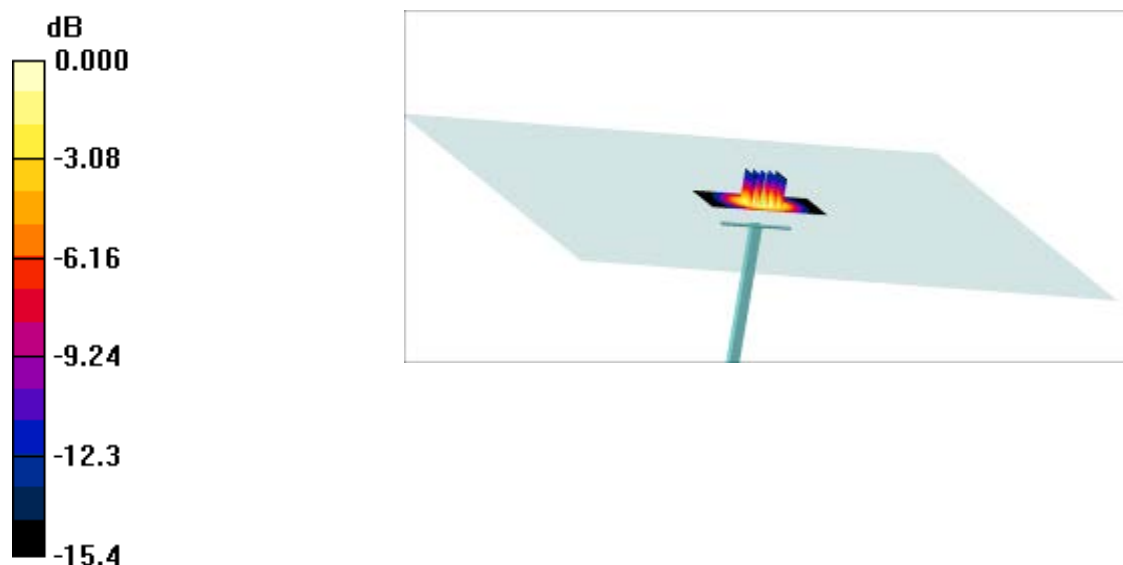


Figure E.1 SAR Performance Check: 0 dB = 3.70mW/g

E.2 System performance check at 900 MHz conducted 08/04/07

Date/Time: 2008-04-07 18:15:11

-Communication System: CW; Frequency: 900 MHz; Duty Cycle: 1:1
-Medium: Head 900 MHz; $\sigma = 0.94$ mho/m; $\epsilon_r = 39.5$; $\rho = 1000$ kg/m³

DASY4 Configuration:

-Probe: ES3DV3 - SN3155; ConvF(6.01, 6.01, 6.01)

-Electronics: DAE3 Sn304

-Phantom: U-flat;

-Measurement SW: DASY4, V4.7 Build 53; Post processing SW: SEMCAD, V1.8 Build 172

d=20mm, Prad = 250.9 mW /Area Scan (61x81x1): Measurement grid: dx=15mm, dy=15mm
Maximum value of SAR (interpolated) = 2.11 mW/g

d=20mm, Prad = 250.9 mW /Zoom Scan (7x7x7) /Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 35.7 V/m; Power Drift = -0.042 dB

Peak SAR (extrapolated) = 2.97 W/kg

SAR(1 g) = 2 mW/g; SAR(10 g) = 1.34 mW/g

Maximum value of SAR (measured) = 2.14 mW/g

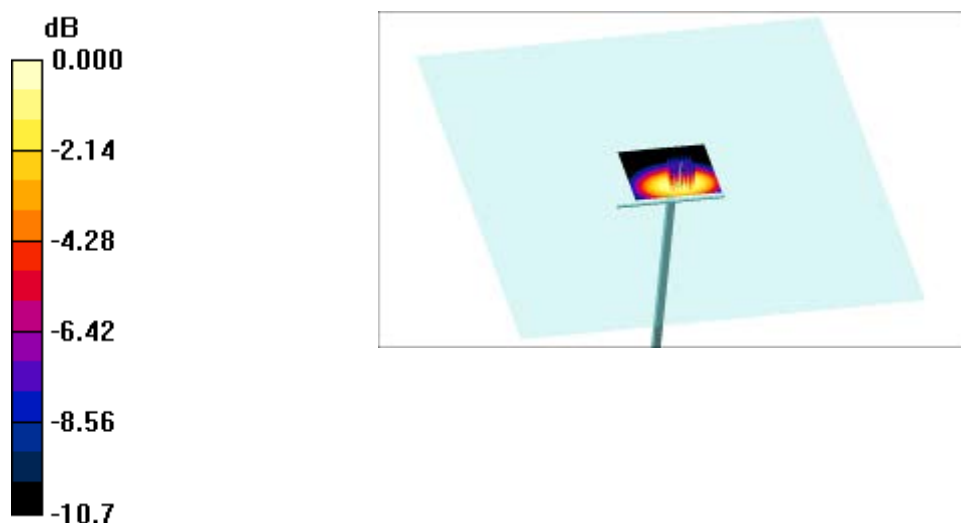


Figure E.2 SAR Performance Check: 0 dB = 2.14mW/g

Annex B (informative)

Roof-top case study with nearby apartments

This annex contains the Roof-top case study referred to in 4.3. This evaluation report is presented as issued by Industry Canada and retains its original structure, formatting, layout and numbering. The standard referred to in the report is IEC 62232.

Industry Canada

Evaluation Report

Montréal, Canada

Josette Gallant
04/06/2009

Evaluation Report Template

Date of Report: May 2009	
Title: Verification of RF exposure compliance of site with cellular base stations from two different service providers.	
Site Location: A building in Montreal	
Site Coordinates (at Tower base): removed	
Google Earth Hyperlink: removed	
Evaluation laboratory: Industry Canada	Company/Client: Industry Canada
Evaluation performed by: Larbi Dini Mathieu Gemme Vladimir Avridor Sylvain Faucher	Date of Evaluation: April 15-28, 2009
Identification number of original report:	
Assessor: Sylvain Faucher _____	Quality Assurance: David Parcigneau _____

1. Executive Summary

The purpose of this case study was to verify the RF exposure levels in the accessible areas of an office building roof-top with a cellular base station, are below the uncontrolled environment exposure limits in Health Canada's Safety Code 6 Guidelines. The building roof-top has cellular base station panel antennas from two separate operators, and is located near an apartment building, residential and commercial areas.

The Equipment Under Test (EUT) was categorised as a Complex RBS as there are multiple antenna systems at the site under evaluation

This assessment was done by Industry Canada as part of their regulatory auditing program of radio communication and broadcasting sites. The assessment consisted of computational modelling to determine the RF exposure compliance boundaries around the antennas, and on-site frequency selective field strength measurements to determine the RF exposure levels in the accessible areas.

The RF exposure compliance boundary (uncontrolled environment) was assessed to be 6m directly in front of the panel antennas.

The maximum exposure level on the building roof-top was assessed to be 5.1% of Safety Code 6 limits for the uncontrolled environment. This was on the southwest side of the roof-top underneath the cellular base station panel antennas.

The maximum exposure level on the building adjacent to the base station was assessed to be 0.51% of Safety Code 6 limits for the uncontrolled environment. This was on the roof-top car park.

Results are presented for this case study using both the best estimate and upper 95% CI assessment schemes. The exposure levels reported using the upper 95% CI assessment scheme include the expanded uncertainty in the reported level. The exposure levels reported using the best estimate assessment scheme state the actual level assessed and the uncertainty factor for the measurement equipment only.

2. Evaluation Overview (see Clauses 5 & 6 of the Standard)

2.1. Site operator information

The computational and measurements results presented in this report defined the RF exposure compliance for the site, which contained cellular base stations from two different service providers. These antenna panels were mounted on the roof-top of an office building. The maximum operator output powers were 1.96 kW EIRP for CDMA, 689 W ERP for GSM 850 and 1.16 kW EIRP for GSM 1900.

Table 1: Operator technology information

Operator	Technology
Cellular Service Provider A	CDMA
Cellular Service Provider B	GSM 850, GSM 1900

2.2. Site environment

The cellular base station antenna panels are mounted on the roof-top of an office building. These antenna systems are not accessible to the general public as the door to the roof-top is locked at all times. Maintenance workers can however have access to roof-top of the building. There are no signs indicating high radio frequency energy placed in the vicinity of the antenna systems.

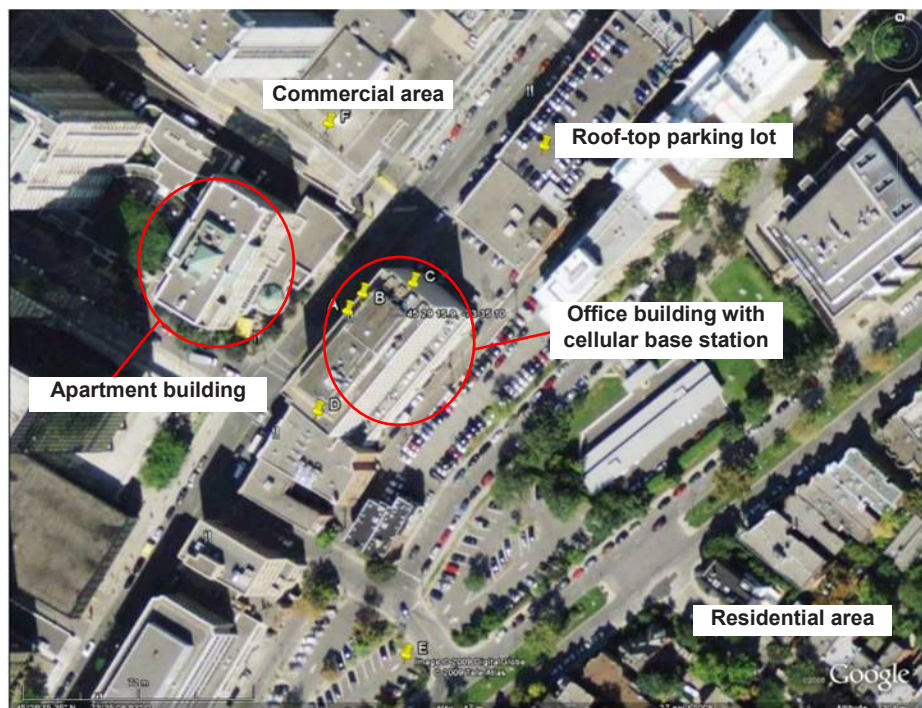


Figure 1: Area map with identified measurement locations



Figure 2: View of the cellular base station antennas from the street

2.3. Exposure safety limits

Industry Canada has adopted the uncontrolled environment limits set forth in Health Canada's Safety Code 6 (SC6) guidelines titled *Limits of Human Exposure to Radiofrequency*

Electromagnetic Energy in the Frequency Range from 3 kHz to 300 GHz for the protection of the general public. As part of their licensing requirements, operators must ensure that their radio communication and broadcasting antenna systems comply at all times with these regulatory limits. Safety Code 6 permissible exposure limits vary depending on frequency. The lowest limits occur over the frequency range 30 to 300 MHz. Permissible limits given for microwave frequencies are somewhat higher. The Safety Code 6 guidelines contain two tiers; limits for controlled environments and limits for uncontrolled environments. The reference limits can be summarised in Table 2 below.

Table 2: Health Canada's Safety Code 6 reference limits for Controlled and Uncontrolled Environments.

Frequency (MHz)	SC6 Uncontrolled Environment Limit (Wm^{-2})	SC6 Controlled Environment Limit (Wm^{-2})
30 MHz to 300 MHz	2	10
300 MHz to 1.5GHz	$f/150$	$f/30$
1.5 GHz to 150 GHz	10	50
150 GHz to 300 GHz	$6.67 \times 10^{-5} f$	$3.33 \times 10^{-4} f$
Note: Averaging time of 6 minutes		

3. Evaluation Plan (see Clauses 5.1, 5.2 & Annex A of the Standard.)

3.1. Pre-evaluation review

The purpose of the pre evaluation review is to develop an estimate of the expected field strength and consequently select appropriate evaluation methods for a given evaluation purpose.

3.1.1. Determine evaluation purpose

The purpose of the survey was to verify RF exposure compliance of the radio communication site as part of Industry Canada's auditing program.

3.1.2. Determine equipment under test (EUT) category

The equipment under test is defined as a complex RBS as there are multiple antenna systems at the site under evaluation.

3.1.3. Determine physical parameters

The antenna parameters are given in this clause.

Table 3: Physical parameters for the antenna systems from service provider A

Parameters	Cellular Base Station Antenna 1	Cellular Base Station Antenna 2	Cellular Base Station Antenna 3
Antenna Type Number	RR33-18-04DPL4	RV33-18-04DPL4	RV65-18-00DPL2
Horizontal HPBW	33°	33°	65°
Vertical HPBW	12°	12°	6°
Directional / omni	Directional	Directional	Directional
Orientation	40°	235°	310°
Broadcast Channels	1850 - 1990 MHz	1850 - 1990 MHz	1850 - 1990 MHz
Maximum Transmit Power W	250 W	250 W	250 W
Typical Transmit Power W	-	-	-

Table 4: Physical parameters for the antenna systems from service provider B

Parameters	Cellular Base Station Antenna 1	Cellular Base Station Antenna 2	Cellular Base Station Antenna 3
Antenna Type Number	7750.1C0.0002.00	TA-824-4-65	7250.04
Horizontal HPBW	69° / 63°	65°	65°
Vertical HPBW	14.3° / 6.6°	19°	5.5°
Directional / Omni	Directional	Directional	Directional
Orientation	170° / 190°	30°	30°
Broadcast Channels	824 - 960 / 1710 - 2170 MHz	824 - 896 / 872 - 960 MHz	1850 - 1990 MHz
Maximum Transmit Power W	-	500 W	500 W
Typical Transmit Power W	-	-	-

3.1.4. Decide if ambient fields are to be considered

Since the requirement is to establish the overall cumulative RF exposure for this location, properties of all operational antennas on the site were determined. In addition, an environment search was performed. All data related to broadcasting stations in a radius of 1 km and to land-fixed transmitter stations in the mobile, cellular, PCS, microwave, radar and radio- location services in a radius of 100 meters from the specific site selected for measurements was gathered as they could have an effect on the total RF exposure values. In this case, FM and TV broadcasting systems were located at approximately 2 km and 3 km from the site. While they were not taken into account during the computational evaluation, a scan of the 54 MHz to 765 MHz frequency band using the Narda SRM-3000 was done to determine their contributions to the overall RF exposure level.

3.1.5. Estimate the field at the evaluation point

A computational assessment of the site was done using HiField, the internal simulation software developed by Industry Canada for verifying RF exposure compliance before actual measurements were done at the site. The results of the simulation established the compliance contours related to Safety Code 6 limits for the uncontrolled environment as well as providing information on the measurement locations with highest RF exposure levels.

3.1.6. Establish which parameters are to be evaluated

The power density values (S) were determined for each measurement locations. However, the results were presented as a percentage (%) of Safety Code 6 limits for the uncontrolled environment.

3.2. Select evaluation method

A computational assessment and on-site frequency selective field measurements were chosen as the evaluation methods for verifying RF exposure compliance of the site.

3.3. Complete the evaluation plan

The following tables represent a check sheet for computational and on-site measurements, respectively.

Table 5: Computational evaluation check list

Step	Description
1	Enter HiField project name
2	Specify study site geographic coordinates
3	Specify search area radius for nearby stations
4	Specify default vertical pattern for stations without antenna patterns
5	Adjust ground levels and radiating centers
6	Validate or exclude nearby stations
7	Use the tower editor to manage tower locations and ASML height
8	Modify, if need be, other nearby stations parameters
9	Plot SC-6 contours: • Set reflection flat plane elevation • Determine reflection plan to study • Enter parameters corresponding to the chosen plane
10	Analyse results