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Edition 1.0 2011-05

TECHNICAL REPORT

colour inside

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

IEC/TR 62669:2011(E)

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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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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- withdrawn,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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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.

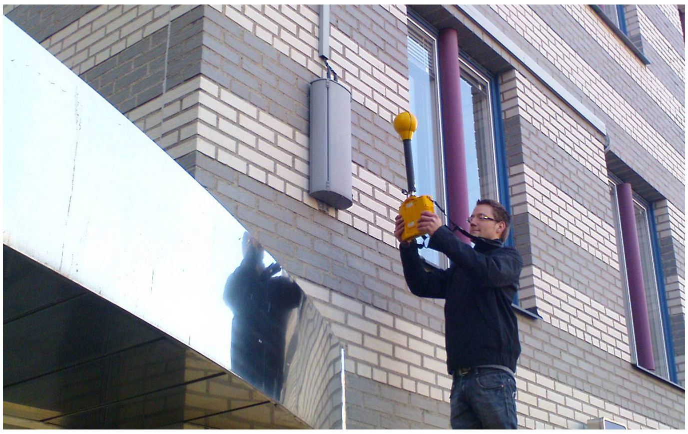

Figure 1 – Micro cell case study

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.

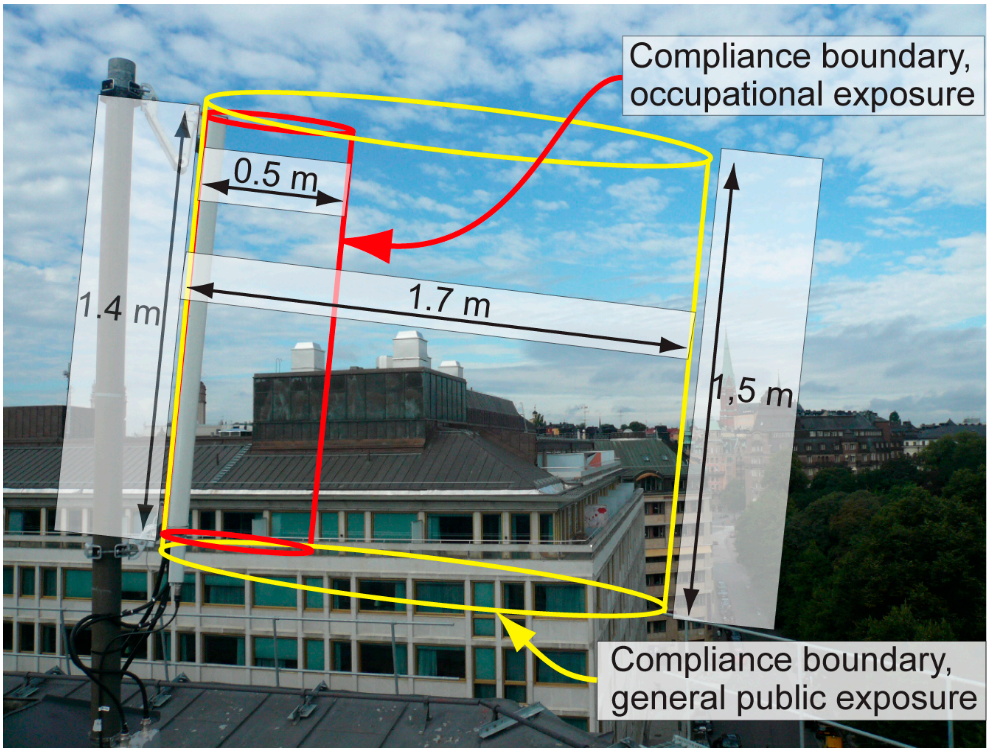

Figure 6 – Cylindrical compliance boundary determination for dual band antenna on building

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.

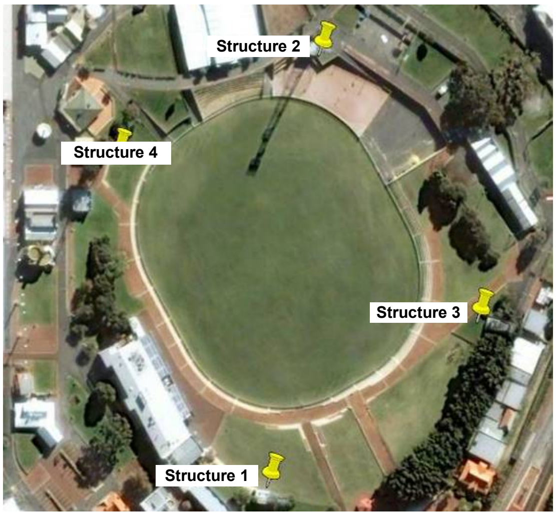

Figure 8 – Multiple towers case study at sports venue

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 μW/cm2 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

Ericsson AB

Evaluation Report

Building Stockholm, Sweden

Björn Hansson
10/4/2008

Evaluation Report Template

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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 know 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) WCMDA 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.

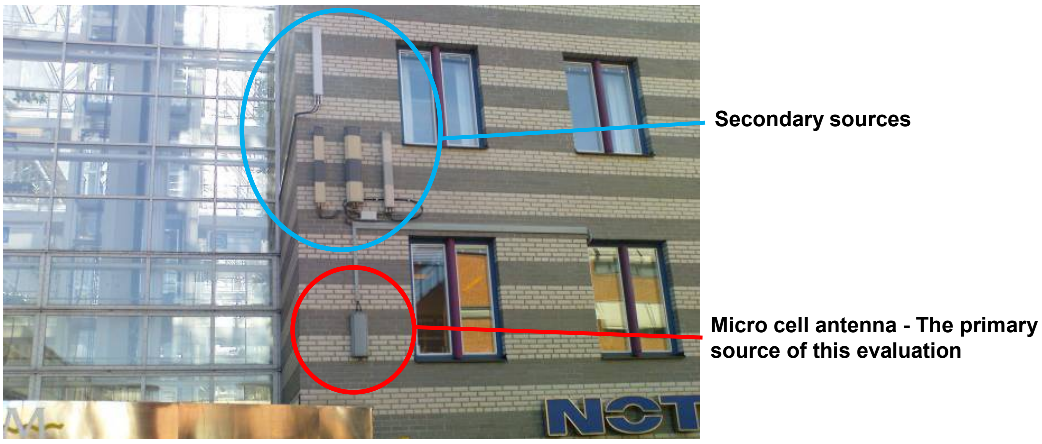

Figure 2.2 Photograph of micro cell antenna

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 ±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).

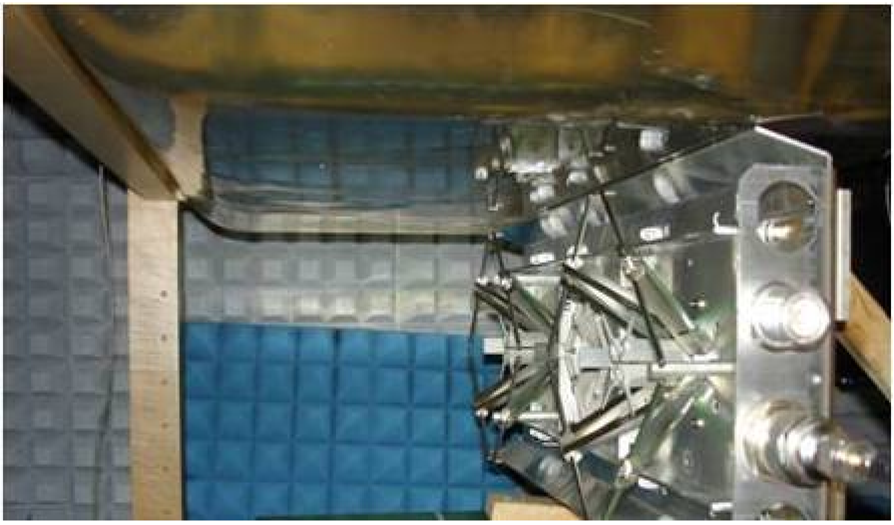

Figure 3.4 SAR testing view from below showing the antenna without radome positioned with one of its sides facing the phantom shell.

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 0.06[1] 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

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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^2u^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^2u^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^2u^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^2u^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 ±10.7% for 10g SAR assessments and the corresponding expanded uncertainty (k=1.96) is ±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 mm ±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 ±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.

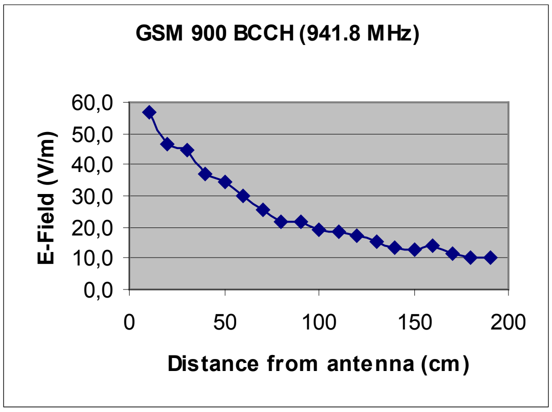
Frequency (MHz)	**EUT position**	**Distance to liquid surface (m)**	**Measured output power (dBm)**	**Max SAR_{10g} (W/kg)**	
				Measured	**Normalized to maximum[9] output power, 37 dBm**
941.8	Front facing phantom	0.007	34.7	6.71	11.4
		0.032	33.9	2.06	4.2
		0.057	34.9	1.21	2.0
		0.082	35.5	0.78	1.1
		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.



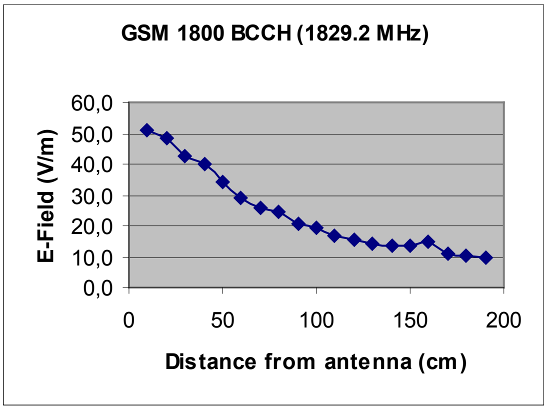


Figure D.1 — Measured electric field (V/m) at the broadcast channel of both GSM 900 and GSM 1800 for distances from the antenna front ranging from 0.1 m to 1.9 m.

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; σ = 1.39 mho/m; ε_r = 38.5; ρ = 1000 kg/m^3

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

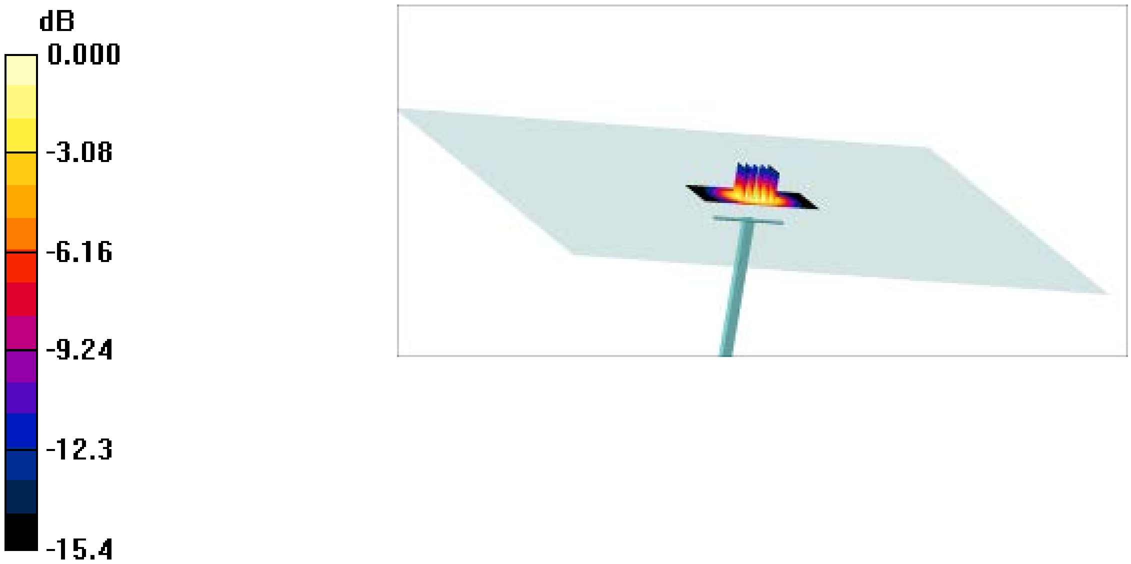


Figure E.1 SAR Performance Check: 0 dB = 3.70mW/g

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; σ = 0.94 mho/m; ε_r = 39.5; ρ = 1000 kg/m^3

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

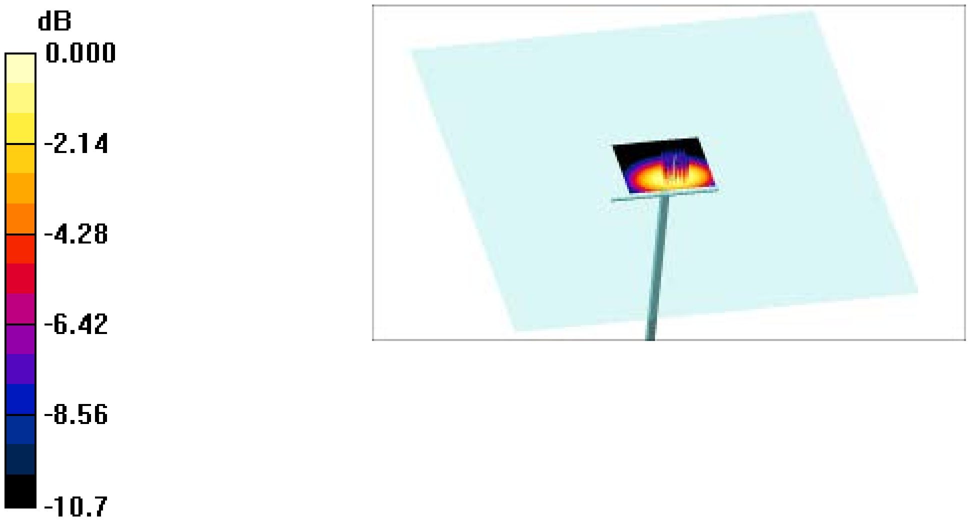


Figure E.2 SAR Performance Check: 0 dB = 2.14mW/g

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.

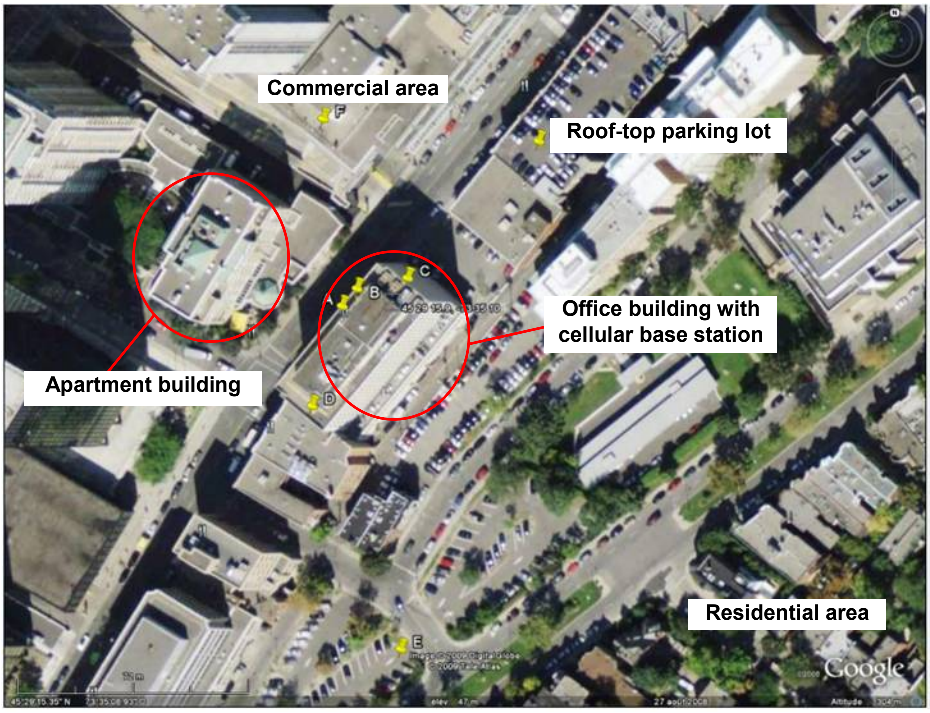


Figure 1: Area map with identified measurement locations

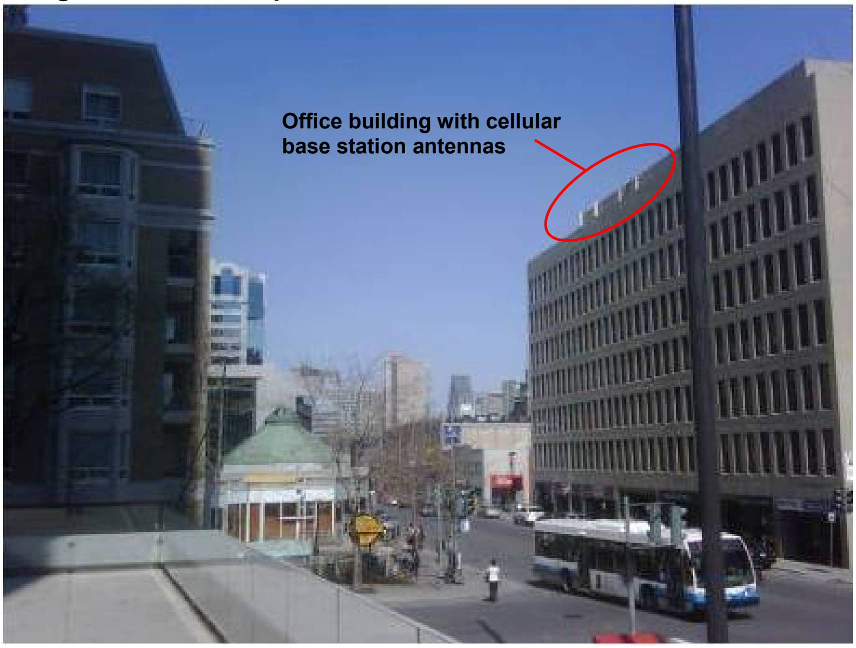


Figure 2: View of the cellular base station antennas from the street

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	6.67×10^{-5} f	3.33×10^{-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

Table 6: On-site measurement check list

Step	Methods
1	Identify the site location where the strongest field level was computed by the software Hifield. Schedule wisely specific time that the transmitters perform at full capacity in order to get maximum results.
2	On-site, use the probe to fine tune to get the strongest field level.
3	Take measurements for a total of 6 minutes in order to evaluate the magnitude of the temporal variations of the signals. If the field signal variations are less than 20 % (or power density 36%), which are normally expected for broadcasting sites, time averaging will not be required for the remaining survey (ref Safety Code 6). If the field signal variations are over 20 % (or power density 36 %), time averaging over 6 minutes is required for the remaining measurements.
4	Walk around the site to make sure that no other points give a stronger field level signal than calculated with the software Hifield.
5	Depending of the results in step 3, if the measurements are between averaging (1±0.36), take each point of a 9 point matrix representing the cross-section of a human body should be logged for 30 seconds. If a measurement is out of the range (1±0.36), then time averaging measurements are required, each point of a 9 points matrix representing the cross-section of a human body should be logged for 6 minutes using a non-metallic tripod.

3.4. **General methodology- field evaluation spatially averaged** (see Clause 6.2.2 of Standard)

When on-site measurements are required to verify RF exposure compliance, the following steps should to be taken into account:

- Prior to on-site measurements, an environment search should be performed (see Clause 3.1.4 of this report).
- Depending on the results of the environmental search, narrowband and broadband equipment are selected for on-site measurements
- Computation evaluation should be made to estimate RF levels in the far field for the surveyed transmitter site(s) as a way to identify approximate locations to be measured (see Clause 3.4 of this report).
- 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, then an E-field probe is sufficient. Otherwise both E-Field and H-field should be measured.
- A written record should be kept of the measurement locations, reading levels and logging time.
- Measurement uncertainties must be taken into account during the survey.
- On-site measurements should be made with a clear view of the antennas. In the case of roof-top sites, the measurements should be done at least at the locations where a member of the general public could be exposed to the main antenna beam.
- The surveyor should initially characterize the transmission site with regard to the temporal variation of the RF signals. This is done by placing the probe approximately where the theoretical evaluation showed the strongest field level and then use the probe to manually fine-tune the location with the strongest signal within the proximity of the original location. Install the probe on a non-metallic tripod at a height of 1 to 2 meters wherever the signal is stronger. The measurements are logged for a total of 6 minutes in order to evaluate the magnitude of the temporal variations of the signals. If the field signal variations are less than 20 % (or power density 36%), time averaging will not be required for the remaining survey (ref: Safety Code 6). If the field signal variations are over 20 % (or power density 36 %), time averaging over 6 minutes is required for the remaining measurements.

– Once the temporal characterization is completed, the surveyor should walk around the site with a power density meter or a shape probe to identify the locations with stronger field exposure using the results of the theoretical evaluation as starting point. Normally, this is done by holding the probe away from the body as the surveyor should not be standing directly in front or behind the probe with no other object present within a few meters from the surveyor. The probe should also be pointing towards the transmitter. The height of the probe should be kept between 1 and 2 meters above ground level wherever the signal is stronger.

– If the above characterization of the site revealed that no time averaging measurements are required, a quick scan of the probe over the cross sectional area equivalent to a human body is done to determine the spatial averaging value of each measurement location. Normally, a scan of at approximately 30 seconds may be considered provided the probe has a fast response time.

– If time averaging measurements are required, each point of a 9 points matrix representing the cross-section of a human body should be logged for 6 minutes, and then averaged. In this case, the probe should be set on a non-metallic tripod for convenience.

4. Results (see Clause 8 of the Standard)

4.1. Results summary – computational evaluation

The RF exposure levels due to the antennas were calculated with HiField, the internal simulation tool developed by Industry Canada, as well as the data gathered by the cellular service providers. The computational evaluation was performed using the data provided in Table 7. Furthermore, several manual changes were applied prior to the simulations, and are listed below.

Table 7: Nearby stations list

CallSign	ALS ID	City	Max ERP (W)	Ground Lev (m)	Rad Center (m)	Type
SITE328792	7007671760	P-PQ0207	291.9	48	77.7	ALS
SITE328792	7007671759	P-PQ0207	452	48	77.7	ALS
SITE328792	7007671758	P-PQ0207	452	48	77.7	ALS
SITE413984	7007144866	E0578-WE	391	48	77.7	ALS
SITE413984	7007144864	E0578-WE	125.7	48	77.7	ALS
SITE413984	7007144865	E0578-WE	174.3	48	77.7	ALS
SITE413984	7007144859	E0578-WE	314.9	48	77.7	ALS
SITE413984	7007144858	E0578-WE	246.1	48	77.7	ALS
SITE413984	7007144860	E0578-WE	149	48	77.7	ALS

The additional changes were:

- EIRPs were entered manually to take in account the number of channels per sector, which is not currently handled in the internal database.
- EIRPs were corrected for PCS stations (~1900 MHz) since power is considered differently between the database (ERP) and the HiField software (EIRP). The output power would be under-evaluated by a factor of 1.64 if the changes were not made.
- Antenna displacements were not taken in account.
- Inactive records were excluded from the study. The service providers provided a list of active channels at each site.
- The vertical antenna patterns are calculated using a cosine reduction for frequencies between 30 MHz and 54 MHz and a cosine cubed reduction for frequencies greater than 54 MHz by the software.
- Antenna heights were modified using the data provided from the antenna schematic diagrams supplied by the service providers.
- Ground elevations were established using the Canadian Digital Elevation Data (CDED) information.
- The dimensions of each antenna were modified according to the antenna specification sheet.

Table 8 provides the distances for different percentages (%) of Safety Code 6 compliance contours (see Appendix C).

Table 8: Percentage (%) of SC6 contour versus distance

% Safety Code Compliance Contour	Distance
100%	6 meters
50%	10 meters
25%	14 meters
10%	23 meters

4.2. Results summary – on-site measurements (spatial averaging)

According to the service providers, peak traffic time for the cellular base stations were between noon and 1 PM as well as 5 and 6 PM. Therefore, the assessors made all measurements between these time periods to ensure that the measured RF values were at their maximums.

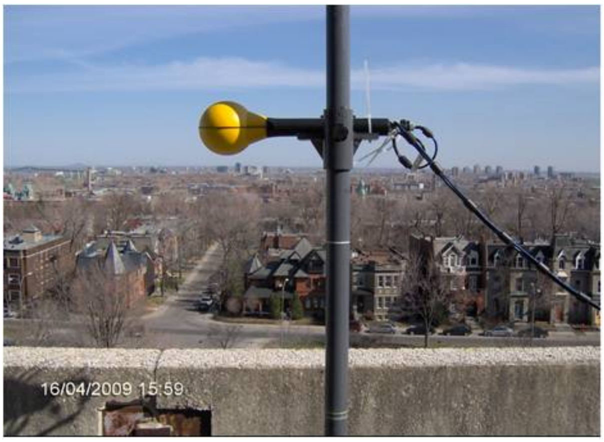


Figure 3: Location D underneath the cellular antenna panels and microwave transmissions links facing a residential area.

Considering the temporal variation of the signals within 6 minutes was less than 20% for the E field (or 36% for power density) during the initial site characterization, spatial averaging measurements were taken for the remaining survey. Each point of the 9 points spatial averaging matrix was measured for approximately 30 seconds. The measurement location with the highest percentage of Safety Code 6 limits for the uncontrolled environment was at location D. This location is situated on the southwest corner of the building underneath some of the base stations antenna panels facing a residential area.

Tables 9 and 10 represent the values at each measurement point in the 9 points spatial averaging scheme for three different frequency bands in which the radio communication and broadcasting services operate. Table 9 includes the results without the measurement equipment uncertainties, while Table 10 includes the results with the measurement equipment uncertainties. As part of the regulatory requirements for radiocommunication and broadcasting antenna systems, the measurement equipment uncertainty must be added to the measured values before comparing them to the RF exposure limits. The field strength measurement and computational uncertainties are described in Appendix A.

The maximum value measured was 5.1% of Safety Code 6 for the uncontrolled environment at that location. However, since the general public does not have access to the roof-top, additional measurements were taken in publically accessible areas. In areas where the general public have access, the maximum RF value was 0.51% (see Location G) of Safety Code 6 for the uncontrolled environment.

Table 9: Percentage (%) of SC6 (excluding expanded uncertainty) at each point of the 9-points spatial averaging scheme for Location D.

9 points spatial avg	Height (meter)	869 MHz -894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	54 MHz-765 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.51	0.09	0.02	0.62
2	1.125 m Right	1.75	0.11	0.04	1.89
3	1.75 m Right	5.23	0.15	0.05	5.43
4	0.5 m Center	0.56	0.09	0.02	0.67
5	1.125 m Center	1.04	0.10	0.03	1.18
6	1.75 m Center	5.63	0.11	0.05	5.79
7	0.5 m Left	0.76	0.07	0.02	0.85
8	1.125 m Left	1.70	0.16	0.04	1.90
9	1.75 m Left	4.93	0.12	0.05	5.10
				Total	23.43
				9 points Spatial Avg	2.60

Table 10: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for Location D.

9 points spatial avg	Height (meter)	869 MHz -894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	54 MHz-765 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	1.01	0.17	0.04	1.22
2	1.125 m Right	3.43	0.21	0.07	3.71
3	1.75 m Right	10.24	0.30	0.10	10.64
4	0.5 m Center	1.09	0.18	0.04	1.31
5	1.125 m Center	2.04	0.20	0.07	2.30
6	1.75 m Center	11.04	0.21	0.09	11.35
7	0.5 m Left	1.49	0.13	0.05	1.67
8	1.125 m Left	3.32	0.32	0.07	3.72
9	1.75 m Left	9.67	0.23	0.10	9.99
				Total	45.91
				9 points Spatial Avg	5.10

An apartment building with balconies was also located at approximately 40 meters in front of the office building where the cellular base station antennas are mounted. Since the assessors could not have access to these balconies, RF compliance at these sites was determined by verifying the RF exposure level in front of the antenna panels facing this building. By elevating the SRM-3000 probe above the head of the assessor, the highest RF level reached was approximately 6% of Safety Code 6 limits for the uncontrolled environment.

In addition, by looking at the computational evaluation results (see Clause 4.1 and Appendix C), one could assess that the RF field value on the balconies would be in compliance with the Safety Code 6 limits for the uncontrolled environment considering the 10% Safety Code 6 contour is located at 23 meters while the balconies are situated at approximately 40 meters from the antenna panels, and at a lower height compare to the roof-top of the office building.

Figure 4: View of the apartment building from the roof-top of the office building where the cellular base stations antennas are mounted

Figure 5: Assessor evaluated the RF field strength from the antennas facing the apartment building.

The spatial averaging scheme as per Health Canada's Safety Code 6 represents a cross-sectional area of a human body. The measurements are done between 0.5 meters and 1.75 meters with a width of 0.35 meters to capture the variation of field strength due to the ground reflections and scattering from nearby objects. Other spatial averaging methods also exist. For instance, surveyors also use a 9 points spatial averaging scheme with a starting height of 1.1 meters and a maximum height of 1.7 meters with a total width of 0.4 meter (Annex I of IEC 62232). Figure 6 represents the two different spatial averaging schemes described above.

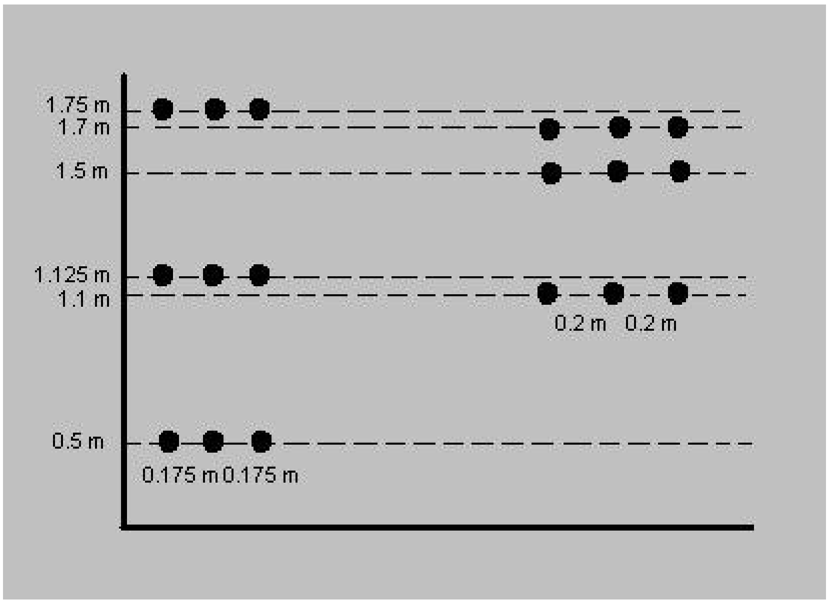


Figure 6: Example of the 9-points spatial averaging scheme as per Safety Code 6 and as Annex I of the IEC 62232

Measurements using the 2 different spatial averaging schemes were done at locations A to G, and the results can be found in Table 9. While the results between the 2 schemes are similar, the 9 points spatial averaging scheme defined in Safety Code 6 is more representative of whole-body exposure.

Table 11: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) between two different 9 points spatial averaging schemes for different locations

Location	9 point spatial averaging per SC6	9 points spatial averaging per Annex I of IEC 62232
A	2.47%	2.83%
B	2.56%	4.42%
C	1.48%	1.90%
D	5.10%	6.17%
E	0.11%	0.12%
F	0.36%	0.32%
G	0.51%	0.57%

4.3. Calculation of compliance boundaries

As the compliance limits in publically accessible areas were not exceeded during the measurements, the location of the compliance boundaries is estimated using the computational evaluation of the site.

According to the results of the simulations (see Clause 4.1 and Appendix C), the compliance boundaries would be located at approximately 6 meters directly in front of the antenna panels. Since the antenna panels are mounted against the building at a height of about 4 meters from the roof-top, maintenance workers would be located outside the compliance boundaries when working.

The maximum RF exposure value measured on the roof-top was 5.1%; well below the RF exposure limit.

4.4. Assessment scheme – interpretation of results (see Clause 8 and Annex M of the Standard)

Results are presented for this evaluation using the best estimate and upper 95% CI assessment schemes.

The exposure levels reported using the upper 95% CI assessment scheme include the expanded measurement equipment 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.

4.5. Further information

Appendix A of this document details the uncertainty values, probability distributions and more for each of the sources of uncertainty related to the measurement and computational analysis.

Appendix B includes the information on the computation tool as well as the measurement equipment used for the on-site measurements.

Appendix C includes the results of the computational evaluation using Industry Canada's internal simulation tool, HiField.

Appendix D includes the on-site results at each location where measurements were taken, and finally, Appendix E contains the measurement scans for each frequency bands evaluated using the Narda SRM-3000.

5. Conclusions

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. This assessment includes the measurement equipment uncertainty.

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. This assessment includes the measurement equipment uncertainty.

Based on the compliance boundary assessment, RF exposure levels assessed on the building roof-top and adjacent buildings, and building access control, this site is determined to be in compliance with Health Canada's Safety Code 6 for the uncontrolled environment.

6. Appendix A (Evaluation Report) - Uncertainty Analysis (see Clause 7 and Annex 0 of the Standard)

6.1. Uncertainty analysis – field strength measurements

The table below represent the expanded uncertainty for the field strength measurements.

Table 12: Expanded uncertainty for the field strength measurements

Source of uncertainty (influence quantity)	Description	unit	prob. distrib. type	semi span *a*	divisor *d*	sens. coeff. *c*	corr. factor *t*	stand. uncert. $u = a/d$	c^2u^2
Measurement equipment Combined instrument uncertainty[1]	As specified by instrument manufacturer for 1800-2200 MHz[2]	dB	normal	2.9	1.96	1	0.23	1.48	2.19
Methodology									
Probe position in high field gradients	Not applicable - test positions not in high field gradients	dB	rect	0	1.73	1	0	0.00	0.000
Field reflections from measurer's body during measurement	Influence of Probe > 1m away from body of the measurer	dB	rect	1.5	1.73	1	0	0.87	0.750
Meter reading error of fluctuating signals	No analog meter reading are done – results stored automatically to memory for downloading to pc	dB	triang	0	2.45	1	0	0.00	0.00
Source and environment									
Spatial Averaging	Averaged uncertainty with a 95 % confidence interval for a 9-point grid	dB	rect	1.8	1.73	1	0	1.04	1.08
Variation in the power of the RF source from the nominal level	Datasheet of radio manufacturer states Output Power uncertainty to be +- 2 dB	dB	rect	2	1.73	1	0	1.15	1.333
Field reflections from movable large objects near the source during measurement	No moving large objects	dB	rect	0	1.73	1	0	0.00	0.000

Source of uncertainty (influence quantity)	Description	unit	prob. distrib. type	semi span a	divisor d	sens. coeff. c	corr. factor t	stand. uncert. $u = a/d$	c^2u^2
RF propagation & environmental clutter loss (for low level environmental measurements)	Low level measurements - low clutter environment	dB	triang	1.5	2.45	1	0	0.61	0.375
Combined correction factor,									0.23
Combined standard uncertainty									2.39
Coverage factor for 95% CI, k									1.96
Expanded Uncertainty, $U = k\ X\ u_c$									4.68

6.2. Uncertainty analysis – desktop modelling software

The table below represent the expanded uncertainty for the desktop modelling software.

Table 13: Uncertainty Assessment for Desktop Computation

Source of uncertainty (influence quantity)	Description	unit	prob. distrib. type	semi span a	divisor d	sens. coeff. c	corr. factor t	stand. uncert. $u = a/d$	c^2u^2
System									
Variation in the radiated power of the RF source	Transmitter power can vary.	dB	rect	2	1.73	1	0	1.15	1.33
Cable and system losses	Long cables connect the transmitters to the antennas.	dB	rect	1	1.73	1	-2.25	0.58	0.33
Radiation Loss	Lossy components inside antennas cause radiation loss.	dB	rect	1.25	1.73	1	-1.25	0.72	0.52
Environmental Uncertainties									
Reflection and Scattering	Scattering and reflections on top of buildings can create hotspots where E-fields add in-phase.	dB	rect	1	1.73	1	0	0.58	0.33
Combined correction factor, $t_c = \sum_{i=1}^{N} t_i$									-3.50
Combined standard uncertainty, $u_c = \sqrt{\sum_{i=1}^{N} (c_i^2\ u_i^2)}$									1.58
Coverage factor for 95% CI, k									1.96
Expanded Uncertainty, $U = k\ X\ u_c$									3.1

7. Appendix B (Evaluation Report) – Equipment List

7.1. Equipment list- desktop computer modelling

The site was assessed using HiField, an internal tool for RF exposure evaluations for radio communication and broadcasting sites developed by Industry Canada.

7.2. Equipment list - on-site field strength

NARDA Selective Radiation Meter (SRM-3000) with tri-axial probe and a 1.5-meter RF extension cable, serial number EC5D1CBA46B88AFD. The last calibration was done on July 30, 2008.

8. Appendix C (Evaluation Report) – Computational Results.

The following graphs are the Safety Code 6 contours in the vicinity of the study site. The area in black represents the near-field. A contour within the near-field would require further investigated such as additional studies and/or measurements to determine the exact locations of compliance boundaries. The red line represents 100% of Safety Code 6 limits for the uncontrolled environment, yellow 50%, brown 25%, and finally, green represents 10% of Safety Code 6 limits for the uncontrolled environment.

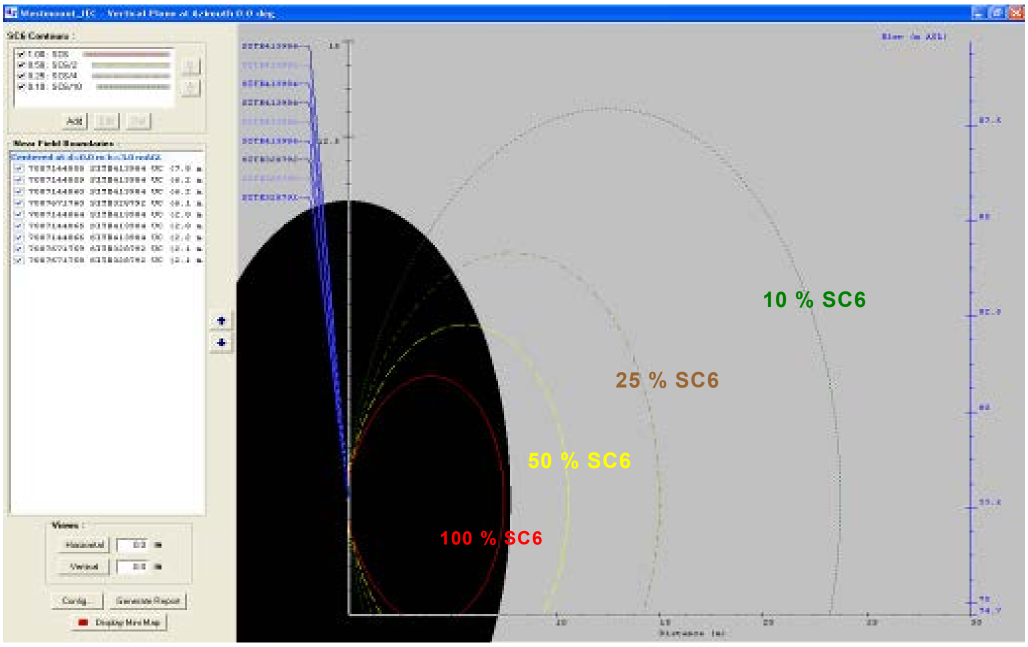


Figure 7: % of SC-6 compliance contours on the roof-top at a height of 74.7 m ASL

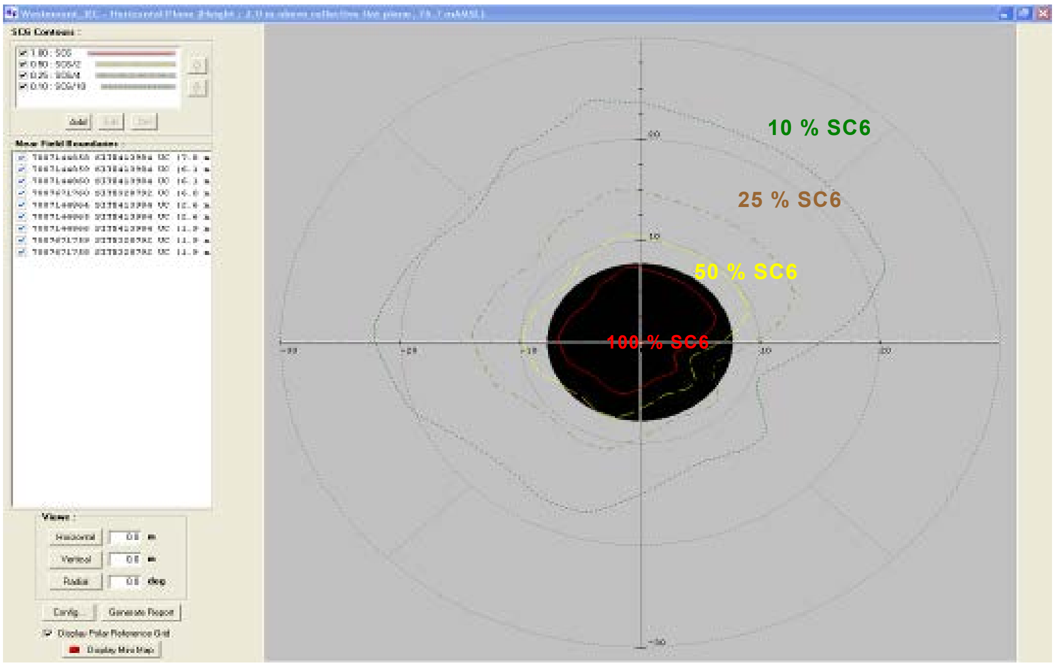


Figure 8: Azimuth view of % of SC-6 compliance contours on the roof-top at a height of 74.7 m ASL and 2 m above the reflective plane

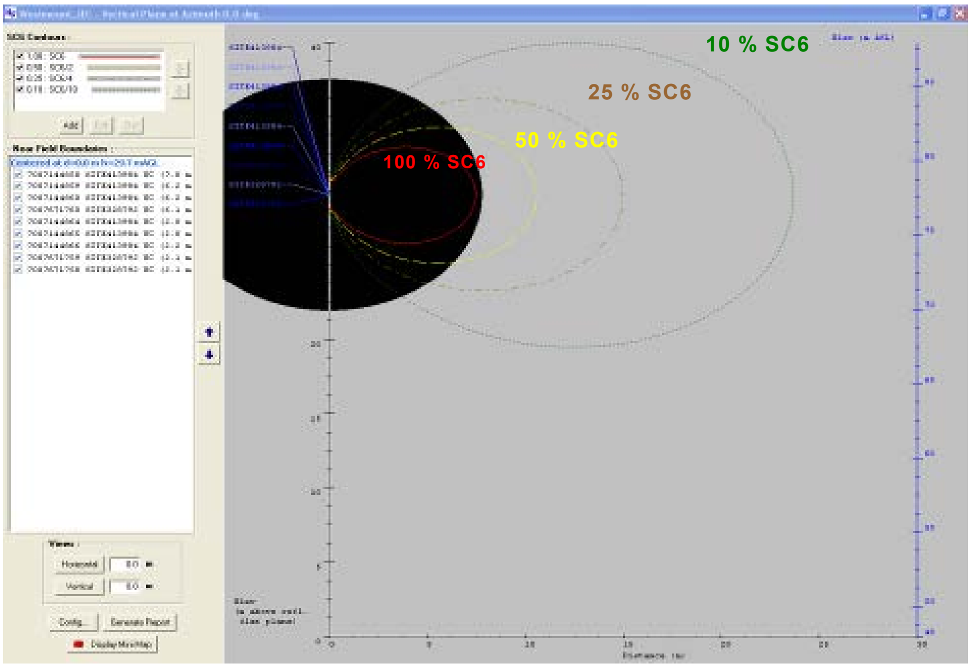


Figure 9: % of SC-6 compliance contours at ground level, at a height of 48 m ASL

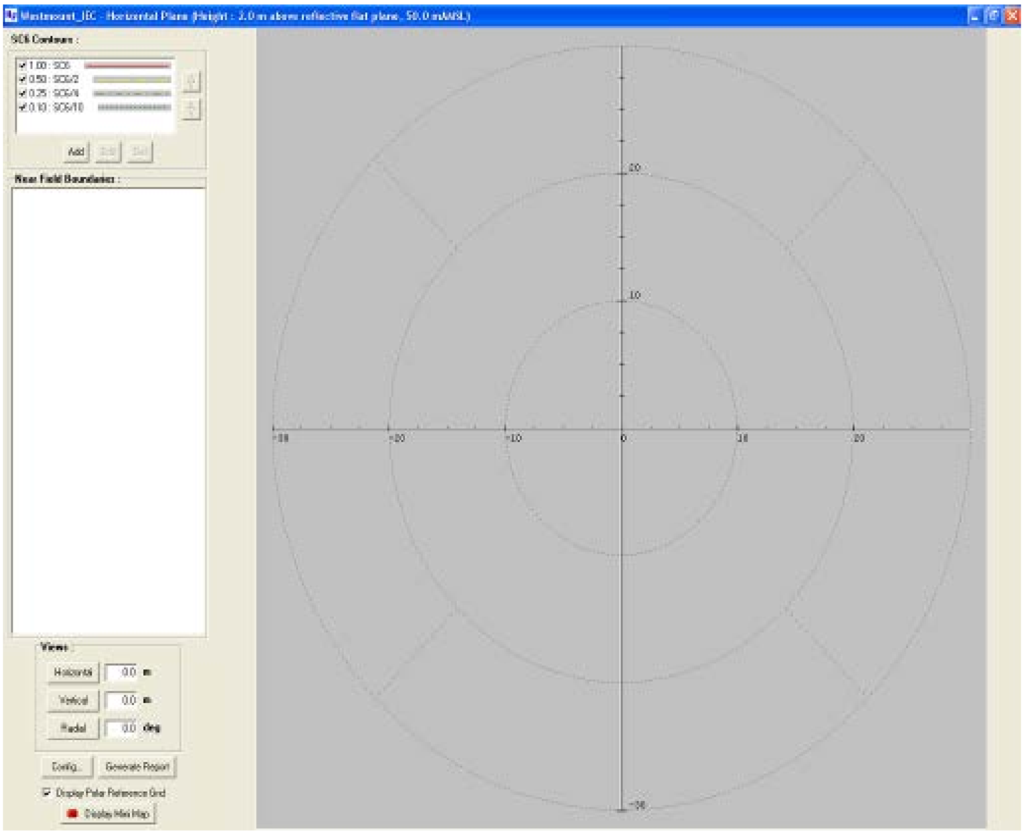


Figure 10: Azimuth view at ground level, at a height of 48 m ASL

9. Appendix D: (Evaluation Report) – On-Site measurement results

The following tables are the measurement values in percentage (%) of Safety Code 6 limits obtained at the locations A to G. Detailed measurement values for location D can be found in Clause 4.2.

Table 14: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location A.

9 points spatial avg	Height (meter)	869 MHz -894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	54 MHz-765 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.90	0.04	0.07	1.01
2	1.125 m Right	2.39	0.07	0.11	2.57
3	1.75 m Right	3.42	0.35	0.17	3.94
4	0.5 m Center	0.79	0.05	0.09	0.93
5	1.125 m Center	2.21	0.10	0.12	2.43
6	1.75 m Center	2.49	0.35	0.16	3.00
7	0.5 m Left	0.92	0.13	0.08	1.13
8	1.125 m Left	2.46	0.44	0.12	3.02
9	1.75 m Left	2.89	1.14	0.15	4.18
				Total	22.21
				9 points Spatial Avg	2.47

Table 15: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location B.

9 points spatial avg	Height (meter)	869 MHz -894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	54 MHz-765 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.22	1.14	0.08	1.44
2	1.125 m Right	0.12	3.36	0.13	3.61
3	1.75 m Right	0.24	3.64	0.22	4.10
4	0.5 m Center	0.15	1.80	0.07	2.02
5	1.125 m Center	0.11	5.29	0.12	5.52
6	1.75 m Center	0.33	3.95	0.20	4.48
7	0.5 m Left	0.20	0.38	0.06	0.64
8	1.125 m Left	0.13	0.19	0.13	0.45
9	1.75 m Left	0.28	0.25	0.20	0.73
				Total	22.99
				9 points Spatial Avg	2.55

Table 16: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location C.

9 points spatial avg	Height (meter)	869 MHz -894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	54 MHz-765 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.31	0.17	0.06	0.54
2	1.125 m Right	0.52	0.22	0.13	0.87
3	1.75 m Right	2.51	0.19	0.09	2.79
4	0.5 m Center	0.50	0.15	0.07	0.72
5	1.125 m Center	0.57	0.29	0.14	1.00
6	1.75 m Center	2.84	0.33	0.11	3.28
7	0.5 m Left	0.43	0.07	0.05	0.55
8	1.125 m Left	0.36	0.22	0.15	0.73
9	1.75 m Left	2.55	0.20	0.13	2.88
				Total	13.36
				9 points Spatial Avg	1.48

Table 17: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location E.

9 points spatial avg	Height (meter)	869 MHz -894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	54 MHz-765 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.02	0.01	0.01	0.04
2	1.125 m Right	0.03	0.02	0.02	0.07
3	1.75 m Right	0.10	0.01	0.04	0.15
4	0.5 m Center	0.06	0.01	0.01	0.08
5	1.125 m Center	0.10	0.01	0.02	0.13
6	1.75 m Center	0.14	0.01	0.04	0.19
7	0.5 m Left	0.06	0.004	0.01	0.07
8	1.125 m Left	0.05	0.01	0.02	0.08
9	1.75 m Left	0.15	0.01	0.04	0.20
				Total	1.01
				9 points Spatial Avg	0.11

Table 18: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location F.

9 points spatial avg	Height (meter)	869 MHz -894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	54 MHz-765 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.15	0.03	0.07	0.25
2	1.125 m Right	0.09	0.06	0.08	0.23
3	1.75 m Right	0.12	0.08	0.11	0.31
4	0.5 m Center	0.23	0.06	0.09	0.38
5	1.125 m Center	0.09	0.05	0.10	0.24
6	1.75 m Center	0.13	0.04	0.12	0.29
7	0.5 m Left	0.16	0.07	0.11	0.34
8	1.125 m Left	0.08	0.69	0.12	0.89
9	1.75 m Left	0.20	0.11	0.12	0.43
				Total	3.36
				9 points Spatial Avg	0.37

Table 19: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location G.

9 points spatial avg	Height (meter)	869 MHz -894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	54 MHz-765 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.45	0.02	0.05	0.52
2	1.125 m Right	0.43	0.01	0.11	0.55
3	1.75 m Right	0.33	0.02	0.18	0.53
4	0.5 m Center	0.63	0.02	0.06	0.71
5	1.125 m Center	0.36	0.02	0.12	0.50
6	1.75 m Center	0.34	0.02	0.18	0.54
7	0.5 m Left	0.35	0.02	0.06	0.43
8	1.125 m Left	0.20	0.01	0.12	0.33
9	1.75 m Left	0.28	0.02	0.16	0.46
				Total	4.57
				9 points Spatial Avg	0.51

10. Appendix E: Measurement Scans

This appendix contains samples measurement scans covering the GSM850, GSM1900 and the CDMA systems.

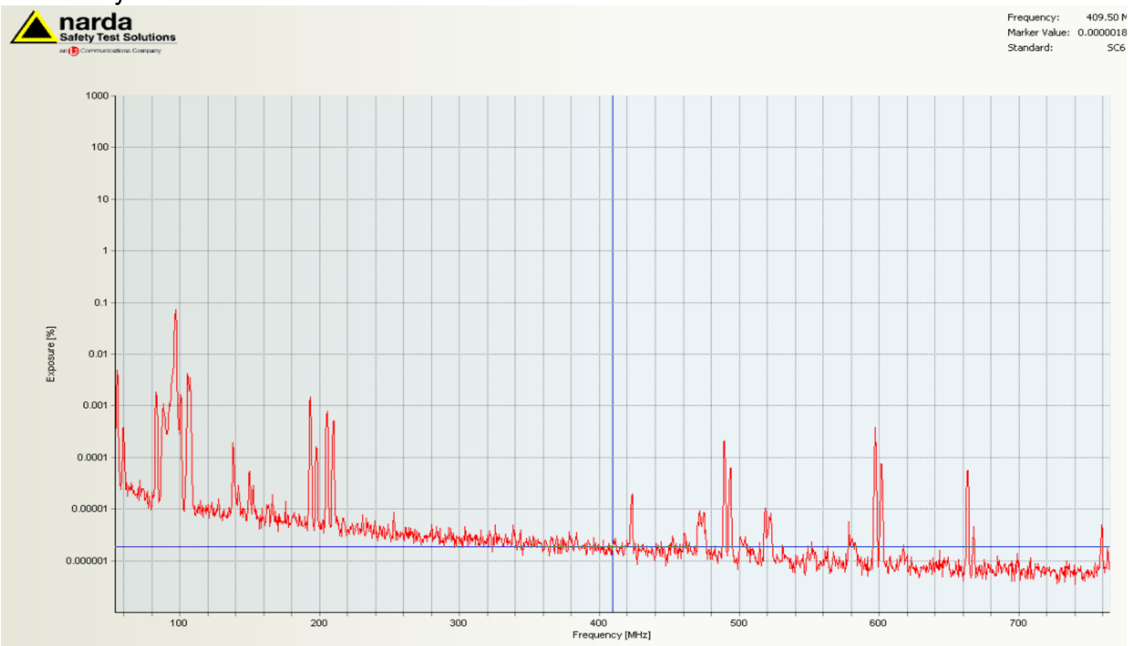


Figure 11: Narda SRM-3000 measurement scan for the frequency range of 54 MHz-765 MHz

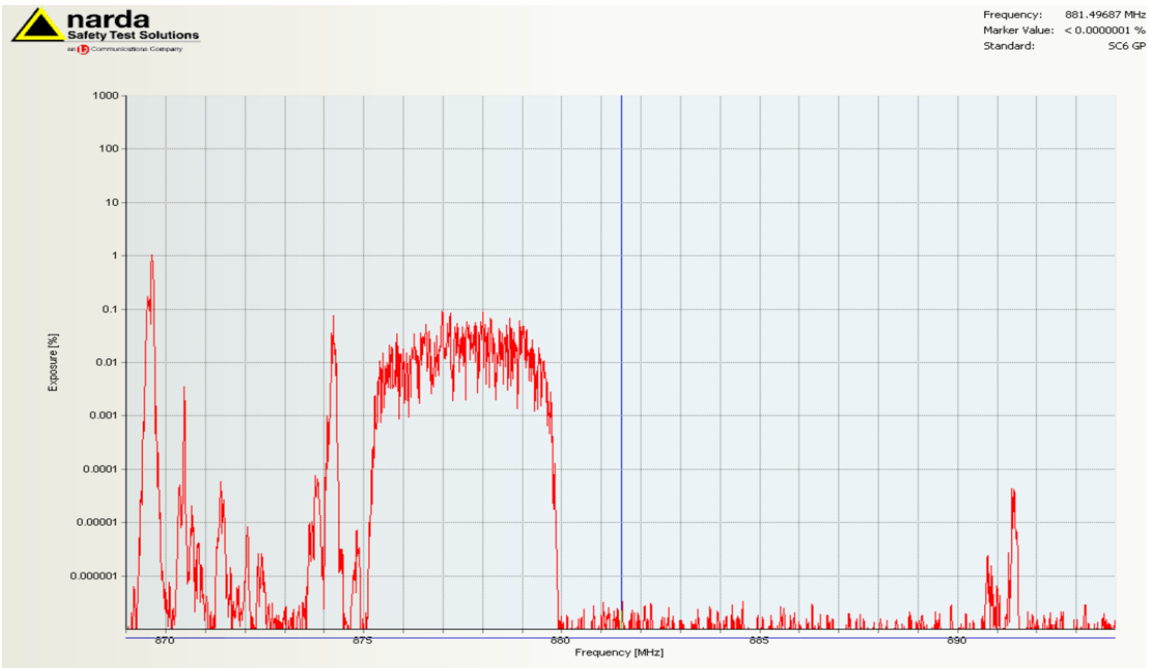


Figure 12: Narda SRM-3000 measurement scan for the 800 MHz frequency range

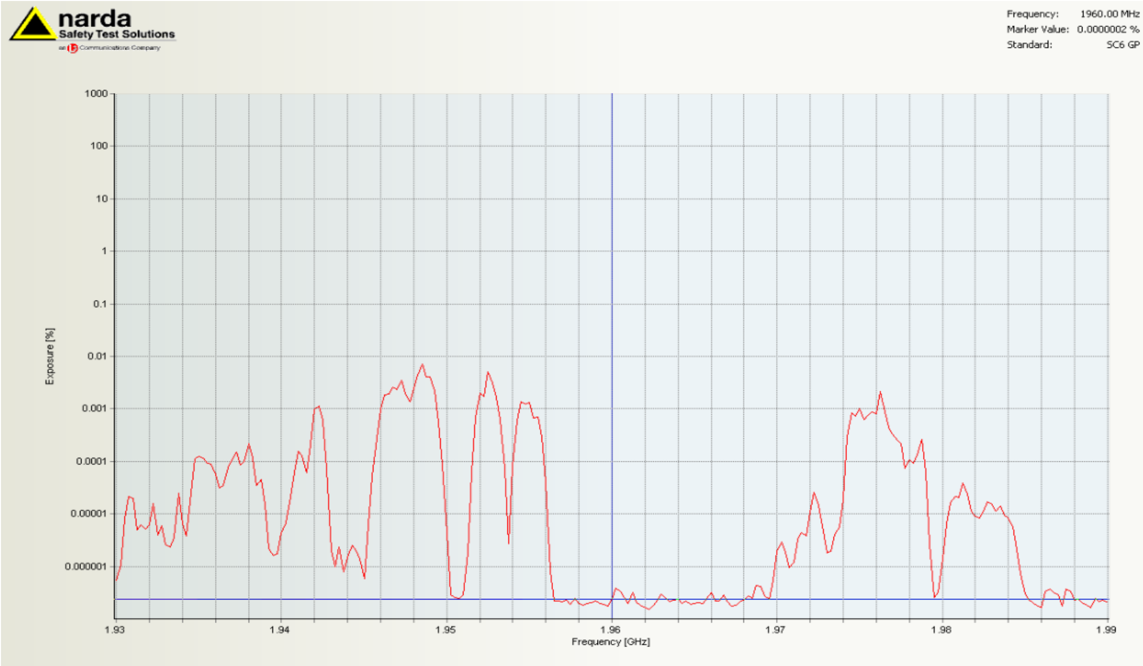


Figure 13: Narda SRM-3000 measurement scan for the 1900 MHz frequency range

Annex C
(informative)

Roof-top / tower case study in residential area

This annex contains the roof-top/tower case study referred to in 4.4. 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

Roof-top in Montreal, Canada

Josette Gallant 04/06/09

Evaluation Report Template

Date of Report: May 2009	
Title: Verification of RF exposure compliance of site with cellular base station and satellite broadcast radio repeater	
Site Location: a roof-top 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 3-14, 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 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 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 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 4m 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 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 Clause 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 a cellular base station and a satellite broadcast radio repeater. These antenna systems were mounted on the second level roof-top of an office building which houses a centre for continuing education. A microwave transmission link was also mounted on the large antenna structure. The maximum operator output power was 500 W ERP for GSM 850 and 500 W EIRP for GSM 1900. The satellite broadcasting repeater had a 800 W ERP (aural peak). As for the microwave transmission, the EIRP was 645.6 W EIRP.

Table 1: Operator technology information

Operator	Technology
Cellular Service Provider	GSM 850, GSM 1900
Satellite Broadcasting Provider	Satellite Digital Audio Radio Service (S-DARS)
Cellular Service Provider	Microwave Transmission

2.2. Site environment

The cellular base station antenna panels are mounted on a large antenna structure located on the second level roof-top of an office building. In the case of the satellite broadcast radio repeater (S-DARS repeater), it is directly mounted on the second level roof-top. These antenna systems are not accessible to the general public as the door to the first level roof-top is locked at all times. Maintenance worker can have access to the first level roof-top of the building. However, they would not be required to go on the second level where the antennas are located for maintenance. A sign indicating high radio frequency energy is placed on the door to the main roof-top as well as on the satellite broadcast radio repeater itself. Figure 3 represents examples of signs when identifying locations with high level of RF energy.

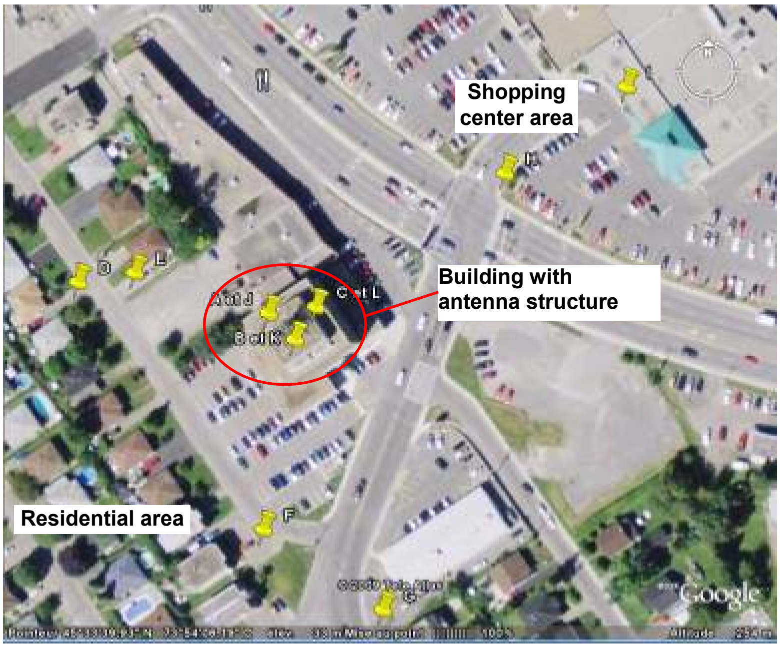


Figure 1: Area map with the identified measurement locations

Figure 2: Photograph of the antenna structure

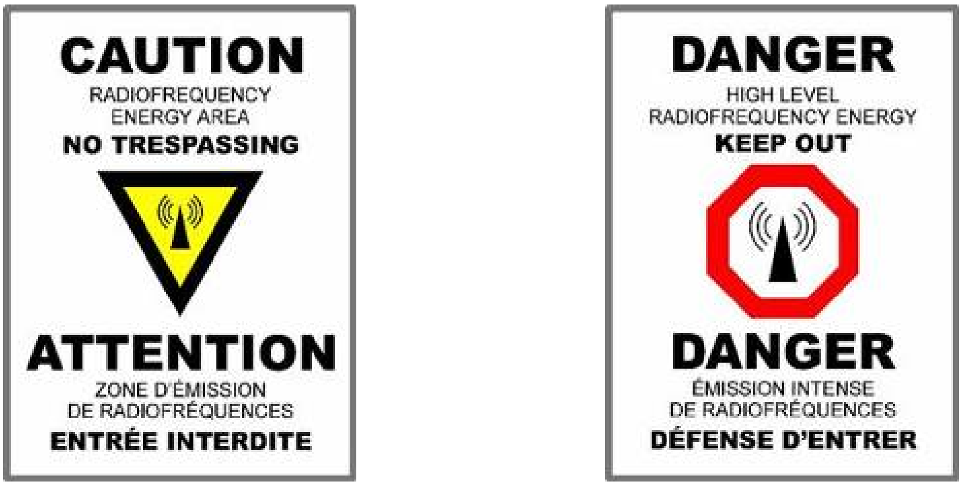


Figure 3: Examples of "Caution" and "Danger" signs

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 the controlled environments and limits for the uncontrolled environments. The reference limits can be summarised in Table 3 below.

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

3. Evaluation Plan (see Clause 5.1, 5.2 & Annex A.)

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

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 and broadcasting 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 multiples antenna systems at the site under evaluation.

3.1.3. Determine physical parameters

The antenna parameters are given in this section.

Table 3: Physical parameters

Parameters	Cellular Base Station Antenna I	Cellular Base Station Antenna II	S-DARS Repeater	Microwave Transmission Link
Antenna Type Number	TA-824-4-90	7740.00	TA-2304-2BAB90	VHLP2-180
Horizontal HPBW	90°	86°	90°	-
Vertical HPBW	18°	6.6°	0°	2.1°
Directoinal / Omni	Directional	Directional	Directional	Directional
Orientation	50°, 170°, 290°	50°, 170°, 290°	270°	214°
Broadcast Channels	824 MHz – 896 MHz	1710 MHz – 2170 MHz / 1850 MHz – 1990 MHz	2330 MHz – 2345 MHz	17.700 GHz – 19.700 GHz
Maximum Transmit Power W	500 W	500 W	800 W	-
Typical Transmit Power W	-	250 W	200 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, no other antenna systems other than the ones located on the roof-top of the building were found when the environment search was performed.

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 4: 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

Table 5: On-site measurement check list

Step	Methods
1	Identify the site location where the strongest field level was computed by the software Hifield. Schedule wisely specific time that the transmitters perform at full capacity in order to get maximum results.
2	On-site, use the probe to fine tune to get the strongest field level.
3	Take measurements for a total of 6 minutes in order to evaluate the magnitude of the temporal variations of the signals. If the field signal variations are less than 20 % (or power density 36%), which are normally expected for broadcasting sites, time averaging will not be required for the remaining survey (ref Safety Code 6). If the field signal variations are over 20 % (or power density 36 %), time averaging over 6 minutes is required for the remaining measurements.
4	Walk around the site to make sure that no other points give a stronger field level signal than calculated with the software Hifield.
5	Depending of the results in step 3, if the measurements are between averaging (1±0.36), take each point of a 9 point matrix representing the cross-section of a human body should be logged for 30 seconds. If a measurement is out of the range (1±0.36), then time averaging measurements are required, each point of a 9 points matrix representing the cross-section of a human body should be logged for 6 minutes using a non-metallic tripod.

3.4. General methodology – on-site measurement (RF field evaluation for time and spatially averaging)

When on-site measurements are required to verify RF exposure compliance, the following steps should to be taken into account:

– Prior to on-site measurements, an environment search should be performed (see Clause 3.1.4 of this report).

– Depending on the results of the environmental search, narrowband and broadband equipment are selected for on-site measurements

– Computation evaluation should be made to estimate RF levels in the far field for the surveyed transmitter site(s) as a way to identify approximate locations to be measured (see Clause 3.4 of this report).

– 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, then an E-field probe is sufficient. Otherwise both E-Field and H-field should be measured.

– A written record should be kept of the measurement locations, reading levels and logging time.

– Measurement uncertainties must be taken into account during the survey.

– On-site measurements should be made with a clear view of the antennas. In the case of roof-top sites, the measurements should be done at least at the locations where a member of the general public could be exposed to the main antenna beam.

– The surveyor should initially characterize the transmission site with regard to the temporal variation of the RF signals. This is done by placing the probe approximately where the theoretical evaluation showed the strongest field level and then use the probe to manually fine-tune the location with the strongest signal within the proximity of the original location. Install the probe on a non-metallic tripod at a height of 1 to 2 meters wherever the signal is stronger. The measurements are logged for a total of 6 minutes in order to evaluate the magnitude of the temporal variations of the signals. If the field signal variations are less than 20 % (or power density 36%), time averaging will not be required for the remaining survey (ref: Safety Code 6). If the field signal variations are over 20 % (or power density 36 %), time averaging over 6 minutes is required for the remaining measurements.

– Once the temporal characterization is completed, the surveyor should walk around the site with a power density meter or a shape probe to identify the locations with stronger field exposure using the results of the theoretical evaluation as starting point. Normally, this is done by holding the probe away from the body as the surveyor should not be standing directly in front or behind the probe with no other object present within a few meters from the surveyor. The probe should also be pointing towards the transmitter. The height of the probe should be kept between 1 and 2 meters above ground level wherever the signal is stronger.

– If the above characterization of the site revealed that no time averaging measurements are required, a quick scan of the probe over the cross sectional area equivalent to a human body is done to determine the spatial averaging value of each measurement location. Normally, a scan of at approximately 30 seconds may be considered provided the probe has a fast response time.

If time averaging measurements are required, each point of a 9 points matrix representing the cross-section of a human body should be logged for 6 minutes, and then averaged. In this case, the probe should be set on a non-metallic tripod for convenience.

4. Results (see Clause 8 of the Standard)

4.1. Results summary – computational evaluation

The RF exposure levels due to the antennas were calculated with HiField, the internal simulation tool developed by Industry Canada, as well as the data gathered by the cellular service providers. The computational evaluation was performed using the data provided in Table 6. Furthermore, several manual changes were applied prior to the simulations, and are listed below.

Table 6: Nearby stations list

CallSign	ALS ID	City	Max ERP (W)	Ground Lev (m)	Rad Center (m)	Type
XMSEU1		SAINT EU	3 380.0	30	54.7	TV
SITE413825	7007143906	E0212-ST	130.4	30	61.1	ALS
SITE413825	7007143907	E0212-ST	130.4	30	61.1	ALS
SITE413825	7007143905	E0212-ST	260.7	30	61.1	ALS
SITE413825	7007143899	E0212-ST	456.3	30	61.1	ALS
SITE413825	7007143901	E0212-ST	456.3	30	61.1	ALS
SITE413825	7007143900	E0212-ST	391.1	30	61.1	ALS
VBB771	51511870001	SAINT EU	393.7	30	62.8	ALS

The additional changes were:

– EIRPs were entered manually to take in account the number of channels per sector, which is not currently handled in the internal database.

– EIRPs were corrected for PCS stations (~1900 MHz) since power is considered differently between the database (ERP) and the HiField software (EIRP). The output power would be under-evaluated by a factor of 1.64 if the changes were not made.

– Antenna displacements were not taken in account.

– Inactive records were excluded from the study. The service providers provided a list of active channels at each site.

– The vertical antenna patterns are calculated using a cosine reduction for frequencies between 30 MHz and 54 MHz and a cosine cubed reduction for frequencies greater than 54 MHz by the software.

– Antenna heights were modified using the data provided from the antenna schematic diagrams supplied by the service providers.

– Ground elevations were established using the Canadian Digital Elevation Data (CDED) information.

The dimensions of each antenna were modified according to the antenna specification sheet.

Table 7 provides the distances for different percentages (%) of Safety Code 6 compliance contours (see Appendix C).

Table 7: Percentage (%) of SC6 contour versus distance

% Safety Code Compliance Contour	Distance for the Cellular Base Antenna	Distance for the Satellite Broadcast Radio Antenna
100%	4 meters	2 meters
50%	7 meters	3 meters
25%	9 meters	6 meters
10%	15 meters	14 meters

4.2. Results summary – on-site measurements (spatial averaging)

Considering that the temporal variation of the signals during 6 minutes was less than 20% for the E field (or 36% for the power density) during the initial site characterization, the surveyors only took spatial averaging measurements for the remaining survey. Each point of the 9 points spatial averaging matrix was measured for approximately 30 seconds. The measurement location with the highest percentage of Safety Code 6 limits for the uncontrolled environment was at location J. This location is situated on the second level roof-top of the office building, a few meters in front of the satellite broadcasting repeater.

Figure 4: Location J in front of the satellite broadcasting repeater

Tables 8 and 9 represent the values at each measurement point in the 9 points spatial averaging scheme for three different frequency bands in which the radio communication and broadcasting services operate. Table 8 includes the results without the measurement equipment uncertainties, while Table 9 includes the results with the measurement equipment uncertainties. As part of the regulatory requirements for radiocommunication and broadcasting antenna systems, the measurement equipment uncertainty must be added to the measured values before comparing them to the RF exposure limits. The field strength measurement and computational uncertainties are described in Appendix A. The maximum value measured was 23.89% of Safety Code 6 for the uncontrolled environment.

Table 8: Percentage (%) of SC6 (excluding expanded uncertainty) at each point of the 9-points spatial averaging scheme for location J.

9 points spatial avg	Height (meter)	869 MHz -894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	2335.7 MHz-2341.8 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.03	0.02	3.56	3.61
2	1.125 m Right	0.02	0.02	13.25	13.29
3	1.75 m Right	0.02	0.01	29.79	29.82
4	0.5 m Center	0.02	0.03	4.95	5.00
5	1.125 m Center	0.03	0.02	13.76	13.81
6	1.75 m Center	0.03	0.012	23.91	23.96
7	0.5 m Left	0.03	0.02	3.36	3.41
8	1.125 m Left	0.02	0.01	7.64	7.67
9	1.75 m Left	0.02	0.01	9.25	9.28
				Total	109.85
				9 points Spatial Avg	12.21

Table 9: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location J.

9 points spatial avg	Height (meter)	869 MHz -894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	2335.7 MHz-2341.8 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.06	0.04	6.98	7.08
2	1.125 m Right	0.04	0.04	25.97	26.05
3	1.75 m Right	0.04	0.02	58.39	58.45
4	0.5 m Center	0.04	0.06	9.70	9.80
5	1.125 m Center	0.06	0.04	26.97	27.07
6	1.75 m Center	0.06	0.02	46.86	46.95
7	0.5 m Left	0.06	0.04	6.59	6.68
8	1.125 m Left	0.04	0.02	14.97	15.03
9	1.75 m Left	0.04	0.02	18.13	18.19
				Total	215.29
				9 points Spatial Avg	23.92

The spatial averaging scheme as per Health Canada's Safety Code 6 represents a cross-sectional area of a human body. The measurements are done between 0.5 meters and 1.75 meters with a width of 0.35 meters to capture the variation of field strength due to the ground reflections and scattering from nearby objects. Other spatial averaging methods also exist. For instance, surveyors also use a 9 points spatial averaging scheme with a starting height of 1.1 meters and a maximum height of 1.7 meters with a total width of 0.4 meter (Annex I of IEC 62232 CDV). Figure 5 represents the two different spatial averaging schemes described above.

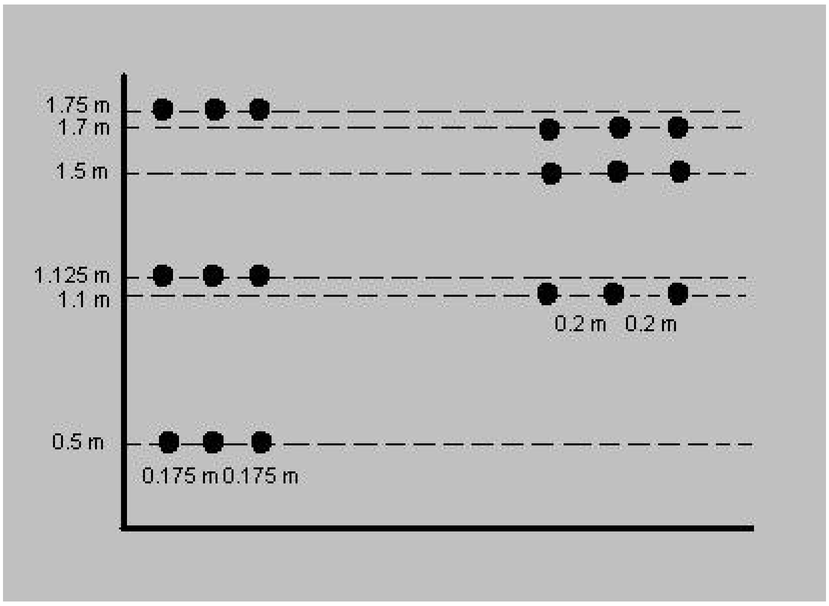


Figure 5: Example of the 9-points spatial averaging scheme as per Safety Code 6 and as Annex I of the IEC 62232 CDV

Measurements were done at different locations using the 2 different spatial averaging schemes, and the results can be found in Table 10. While the results between the 2 schemes are similar, the 9 points spatial averaging scheme defined in Safety Code 6 is more representative of whole-body exposure.

Table 10: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) between two different 9 points spatial averaging schemes for different locations

Location	9 point spatial averaging per SC6	9 points spatial averaging per Annex I of IEC 62232
D	0.038%	0.040%
E	0.040%	0.040%
F	0.023%	0.017%
G	0.036%	0.028%
H	0.026%	0.027%
I	0.044%	0.053%
J	23.921%	25.520%
K	0.166%	0.458%
L	0.272%	0.263%

Finally, the results for the other measurement locations can be found in Table 11. These results include the measurement equipment uncertainties. The detailed measurement values are found in Appendix D.

Table 11: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) for other locations

Location	Total (% of Safety Code 6 for Uncontrolled Environment)
A	18.22
B	0.29
C	0.28
D	0.038
E	0.041
F	0.023
G	0.036
H	0.028
I	0.044
J	23.92
K	0.16
L	0.27

4.3. Calculation of compliance boundaries

As the compliance limits in publically accessible areas were not exceeded during the measurements, the location of the compliance boundaries is estimated using the computational evaluation of the site.

According to the results of the simulations (see Clause 4.1 and Appendix C), the compliance boundary would be located at approximately 2 meters directly in front of the satellite broadcast repeater and 4 meters for the cellular base stations antenna panels. However, considering this is in the near field region of the antenna, additional studies and/or measurements to verify the location of exact compliance boundary would be required.

The maximum RF exposure value measured on the roof-top was 23.92% of the RF exposure limit.

4.4. **Assessment scheme – interpretation of results** (see Clause 8 and Annex M of the Standard)

Results are presented for this evaluation using the best estimate and upper 95% CI assessment schemes.

The exposure levels reported using the upper 95% CI assessment scheme include the expanded measurement equipment 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.

4.5. Further information

Appendix A of this document details the uncertainty values, probability distributions and more for each of the sources of uncertainty related to the measurement and computational analysis.

Appendix B includes the information on the computation tool as well as the measurement equipment used for the on-site measurements.

Appendix C includes the results of the computational evaluation using Industry Canada's internal simulation tool, HiField.

Appendix D includes the on-site results at each location where measurements were taken, and finally, Appendix E contains the measurement scans for each frequency bands evaluated using the Narda SRM-3000.

5. Conclusions

The RF exposure compliance boundary (uncontrolled environment) was assessed to be 4m 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 value includes the measurement equipment uncertainties and the 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. This value includes the measurement equipment uncertainties.

Based on the RF exposure levels assessed in the residential and commercial area, the compliance boundary assessment, and building access control, this site is determined to be in compliance with Health Canada's Safety Code 6 for the uncontrolled environment.

6. Appendix A (Evaluation Report) - Uncertainty Analysis (see Clause 6, 7 and Annex O of the Standard)

6.1. Uncertainty analysis – field strength measurements

The table below represent the expanded uncertainty for the field strength measurements.

Table 12: Expanded uncertainty for the field strength measurements

Source of uncertainty (influence quantity)	unit	prob. distrib. type	semi span *a*	divisor *d*	sens. coeff. *c*	Corr. factor t	stand. uncert. $u = a/d$	c^2u^2
Measurement equipment								
Combined instrument uncertainty[1] As specified by instrument manufacturer for 1800 to 2000 MHz[2]	dB	normal	2.9	1.96	1	0.23	1.48	2.19
Methodology								
Probe position in high field gradients: Not applicable - test positions not in high field gradients	dB	rect	0	1.73	1	0	0.00	0.000
Field reflections from measurer's body during measurement: Influence of Probe > 1m away from body of the measurer	dB	rect	1.5	1.73	1	0	0.87	0.750
Meter reading error of fluctuating signals: No analog meter reading are done – results stored automatically to memory for downloading to pc	dB	triang	0	2.45	1	0	0.00	0.00
Source and environment								
Spatial Averaging - Averaged uncertainty with a 95 % confidence interval for a 9-point grid	dB	rect	1.8	1.73	1	0	1.04	1.08
Variation in the power of the RF source from the nominal level Datasheet of radio manufacturer states Output Power uncertainty to be +- 2 dB	dB	rect	2	1.73	1	0	1.15	1.333
Field reflections from movable large objects near the source during measurement: No moving large objects	dB	rect	0	1.73	1	0	0.00	0.000
RF propagation & environmental clutter loss (for low level environmental measurements)	dB	triang	1.5	2.45	1	0	0.61	0.375
Combined correction factor,								0.23
Combined standard uncertainty								2.39
Coverage factor for 95% CI, k								1.96
Expanded Uncertainty, $U = k\ X\ u_c$								4.68

6.2. Uncertainty analysis – desktop modelling software

The table below represent the expanded uncertainty for the desktop modelling software.

Table 13: Uncertainty Assessment for Desktop Computation

Source of uncertainty (influence quantity)	**unit**	**prob. distrib. type**	**semi span** a	**divisor** d	**sens. coeff.** c	**Corr. factor** t	**stand. uncert.** $u = a/d$	c^2u^2
System								
Variation in the radiated power of the RF source Transmitter power can vary.	dB	rect	2	1.73	1	0	1.15	1.33
Cable and system losses Long cables connect the transmitters to the antennas.	dB	rect	1	1.73	1	-2.25	0.58	0.33
Radiation Loss Lossy components inside antennas cause radiation loss.	dB	rect	1.25	1.73	1	-1.25	0.72	0.52
Environmental Uncertainties								
Reflection and Scattering on top of buildings can create hotspots where E-fields add in-phase.	dB	rect	1	1.73	1	0	0.58	0.33
Combined correction factor, $t_c = \sum_{i=1}^{N} t_i$								-3.50
Combined standard uncertainty, $u_c = \sqrt{\sum_{i=1}^{N} (c_i^2\ u_i^2)}$								1.58
Coverage factor for 95% CI, k								1.96
Expanded Uncertainty, $U = k\ X\ u_c$								3.1

7. Appendix B (Evaluation Report) – Equipment List

7.1. Equipment list- desktop computer modelling

The site was assessed using HiField, an internal tool for RF exposure evaluations for radio communication and broadcasting sites developed by Industry Canada.

7.2. Equipment list - on-site field strength

NARDA Selective Radiation Meter (SRM-3000) with tri-axial probe and a 1.5-meter RF extension cable, serial number EC5D1CBA46B88AFD. The last calibration was done on July 30, 2008.

8. Appendix C (Evaluation Report) – Computational Results

The following graphs are the Safety Code 6 contours in the vicinity of the study site. The area in black represents the near-field. A contour within the near-field would require further investigated such as additional studies and/or measurements to determine where the location of compliance boundaries. The red line represents 100% of Safety Code 6 limits for the uncontrolled environment, yellow 50%, brown 25%, and finally, green represents 10% of Safety Code 6 limits for the uncontrolled environment.

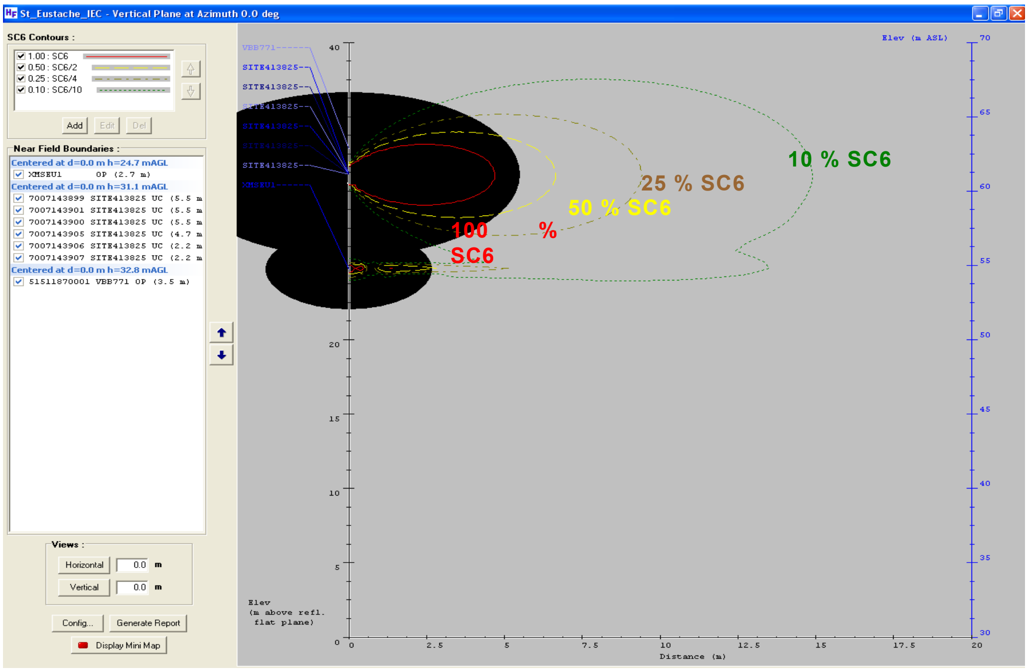


Figure 6: % of SC-6 compliances contours on the roof-top at a height of 52 m ASL

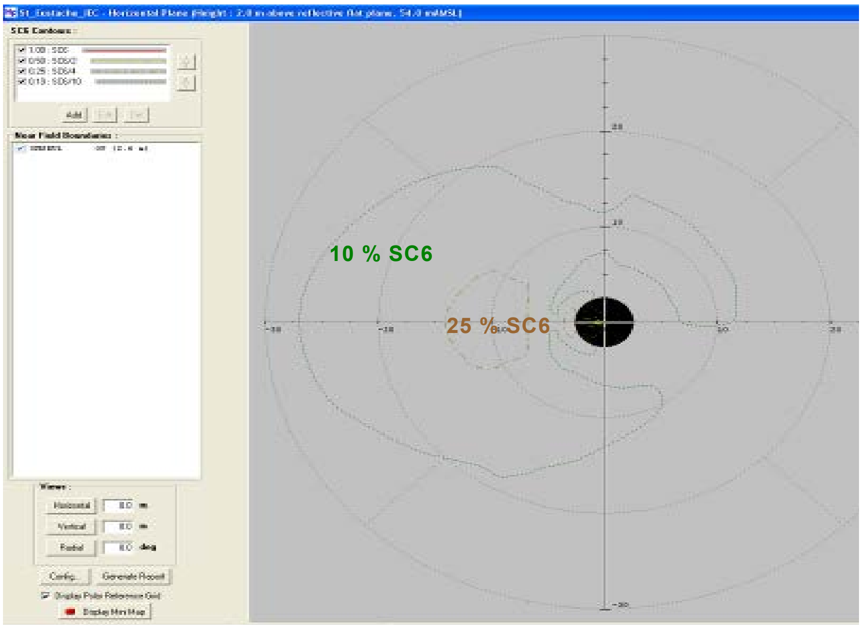


Figure 7: Azimuth view of % of SC-6 compliance contour on the roof-top at a height of 52 m ASL, 2 m above the reflective flat plane

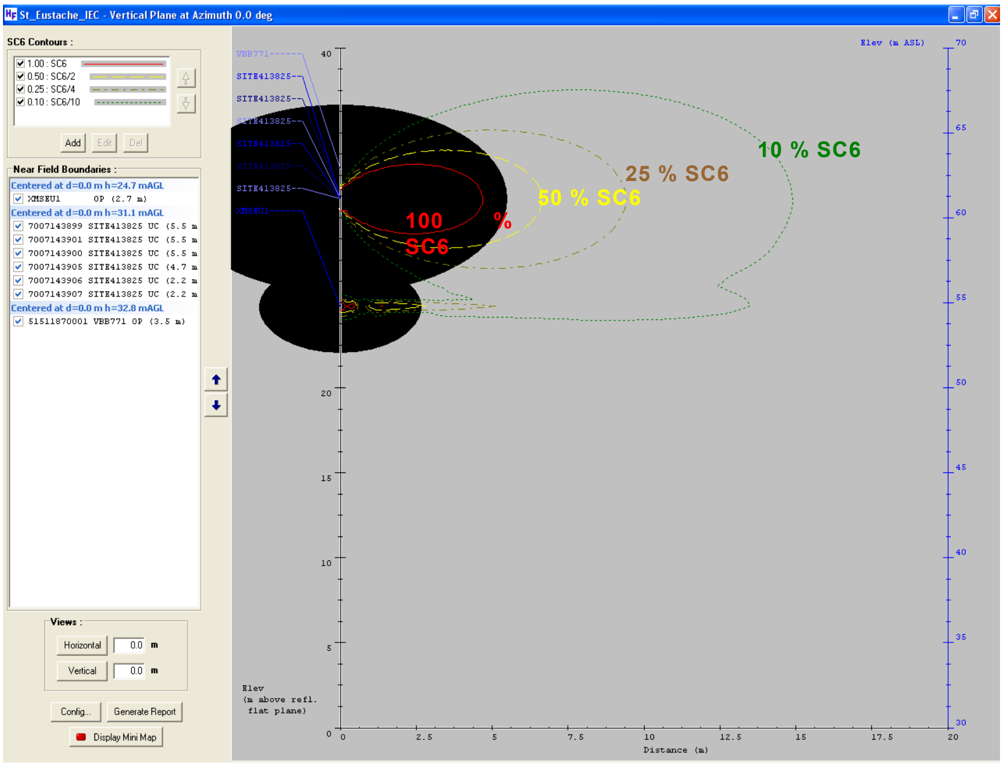


Figure 8: % of SC-6 compliance contours at ground level, at a height of 30 m ASL

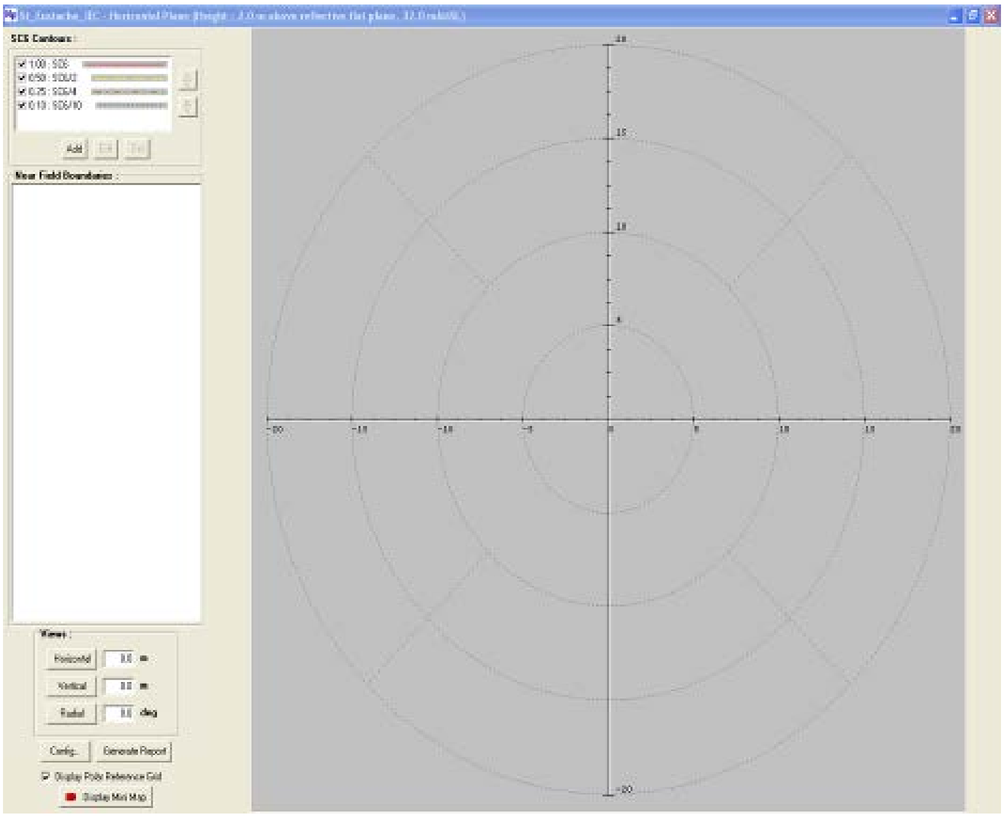


Figure 9: Azimuth view at ground level, at a height of 30 m ASL

9. Appendix D (Evaluation Report) – On-Site measurement results

The following tables are the measurement values in percentage (%) of Safety Code 6 limits obtained at the locations A to L. Detailed measurement values for location J can be found in Clause 4.2.

Table 14: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location A.

9 points spatial avg	Height (meter)	869 MHz -894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz – 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	2335.7 MHz-2341.8 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.06	0.05	4.69	4.80
2	1.125 m Right	0.08	0.02	10.51	10.61
3	1.75 m Right	0.11	0.09	43.79	43.99
4	0.5 m Center	0.04	0.05	1.37	1.46
5	1.125 m Center	0.07	0.02	6.53	6.62
6	1.75 m Center	0.11	0.01	40.01	40.13
7	0.5 m Left	0.04	0.03	2.53	2.60
8	1.125 m Left	0.06	0.02	9.52	9.60
9	1.75 m Left	0.07	0.01	44.05	44.13
				Total	163.94
				9 points Spatial Avg	18.22

Table 15: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location B.

9 points spatial avg	Height (meter)	869 MHz -894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	2335.7 MHz-2341.8 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.09	0.01	0.06	0.16
2	1.125 m Right	0.08	0.01	0.08	0.17
3	1.75 m Right	0.10	0.02	0.07	0.19
4	0.5 m Center	0.13	0.02	0.03	0.18
5	1.125 m Center	0.05	0.01	0.04	0.10
6	1.75 m Center	0.08	0.02	0.35	0.45
7	0.5 m Left	0.06	0.15	0.06	0.27
8	1.125 m Left	0.08	0.03	0.03	0.14
9	1.75 m Left	0.06	0.01	0.86	0.93
				Total	2.59
				9 points Spatial Avg	0.29

Table 16: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location C.

9 points spatial avg	Height (meter)	869 MHz -894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	2335.7 MHz-2341.8 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment
1	0.5 m Right	0.16	0.02	0.01	0.19
2	1.125 m Right	0.25	0.02	0.03	0.30
3	1.75 m Right	0.21	0.03	0.02	0.26
4	0.5 m Center	0.23	0.02	0.03	0.28
5	1.125 m Center	0.20	0.01	0.02	0.23
6	1.75 m Center	0.22	0.03	0.04	0.29
7	0.5 m Left	0.19	0.02	0.02	0.23
8	1.125 m Left	0.17	0.01	0.03	0.21
9	1.75 m Left	0.21	0.02	0.34	0.57
				Total	2.56
				9 points Spatial Avg	0.28

Table 17: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location D.

9 points spatial avg	Height (meter)	869 MHz -894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	2335.7 MHz-2341.8 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.001	0.001	0.004	0.006
2	1.125 m Right	0.002	0.001	0.045	0.048
3	1.75 m Right	0.003	0.001	0.046	0.050
4	0.5 m Center	0.002	0.001	0.041	0.044
5	1.125 m Center	0.002	0.001	0.036	0.039
6	1.75 m Center	0.003	0.002	0.039	0.044
7	0.5 m Left	0.002	0.0004	0.031	0.033
8	1.125 m Left	0.001	0.001	0.033	0.035
9	1.75 m Left	0.002	0.001	0.041	0.044
				Total	0.343
				9 points Spatial Avg	0.038

Table 18: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location E.

9 points spatial avg	Height (meter)	869 MHz - 894 MHz (% of Safety Code 6 Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	2335.7 MHz-2341.8 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.002	0.001	0.022	0.025
2	1.125 m Right	0.002	0.001	0.045	0.048
3	1.75 m Right	0.003	0.002	0.040	0.045
4	0.5 m Center	0.002	0.001	0.029	0.032
5	1.125 m Center	0.002	0.001	0.050	0.053
6	1.75 m Center	0.002	0.001	0.048	0.051
7	0.5 m Left	0.002	0.001	0.037	0.040
8	1.125 m Left	0.002	0.001	0.026	0.029
9	1.75 m Left	0.003	0.001	0.038	0.042
				Total	0.365
				9 points Spatial Avg	0.041

Table 19: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location F.

9 points spatial avg	Height (meter)	869 MHz - 894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	2335.7 MHz-2341.8 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.013	0.002	0.001	0.016
2	1.125 m Right	0.030	0.001	0.001	0.032
3	1.75 m Right	0.023	0.002	0.001	0.026
4	0.5 m Center	0.019	0.001	0.0004	0.020
5	1.125 m Center	0.025	0.001	0.001	0.027
6	1.75 m Center	0.019	0.002	0.001	0.022
7	0.5 m Left	0.018	0.001	0.0005	0.020
8	1.125 m Left	0.024	0.001	0.001	0.026
9	1.75 m Left	0.016	0.001	0.001	0.018
				Total	0.207
				9 points Spatial Avg	0.023

Table 20: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location G.

9 points spatial avg	Height (meter)	869 MHz - 894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	2335.7 MHz-2341.8 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.037	0.001	0.0002	0.039
2	1.125 m Right	0.039	0.002	0.0003	0.041
3	1.75 m Right	0.056	0.002	0.0004	0.058
4	0.5 m Center	0.037	0.001	0.0002	0.038
5	1.125 m Center	0.018	0.003	0.0004	0.021
6	1.75 m Center	0.040	0.003	0.0006	0.044
7	0.5 m Left	0.028	0.001	0.0002	0.029
8	1.125 m Left	0.018	0.002	0.0004	0.020
9	1.75 m Left	0.029	0.004	0.0004	0.033
				Total	0.323
				9 points Spatial Avg	0.036

Table 21: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location H.

9 points spatial avg	Height (meter)	869 MHz - 894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	2335.7 MHz-2341.8 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.008	0.002	0.002	0.012
2	1.125 m Right	0.018	0.001	0.002	0.021
3	1.75 m Right	0.030	0.001	0.002	0.033
4	0.5 m Center	0.017	0.002	0.024	0.043
5	1.125 m Center	0.023	0.001	0.001	0.025
6	1.75 m Center	0.034	0.001	0.002	0.037
7	0.5 m Left	0.013	0.003	0.002	0.018
8	1.125 m Left	0.023	0.001	0.001	0.025
9	1.75 m Left	0.037	0.002	0.002	0.041
				Total	0.255
				9 points Spatial Avg	0.028

Table 22: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location I.

9 points spatial avg	Height (meter)	869 MHz - 894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	2335.7 MHz-2341.8 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.063	0.001	0.0003	0.064
2	1.125 m Right	0.049	0.0002	0.0004	0.050
3	1.75 m Right	0.022	0.002	0.0003	0.024
4	0.5 m Center	0.058	0.0004	0.0002	0.059
5	1.125 m Center	0.039	0.0004	0.0003	0.040
6	1.75 m Center	0.052	0.002	0.0003	0.054
7	0.5 m Left	0.043	0.0002	0.0003	0.044
8	1.125 m Left	0.039	0.0004	0.0003	0.040
9	1.75 m Left	0.024	0.0004	0.0003	0.025
				Total	0.400
				9 points Spatial Avg	0.044

Table 23: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location K.

9 points spatial avg	Height (meter)	869 MHz - 894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	2335.7 MHz-2341.8 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.07	0.02	0.0004	0.09
2	1.125 m Right	0.15	0.03	0.04	0.22
3	1.75 m Right	0.02	0.01	0.03	0.06
4	0.5 m Center	0.06	0.02	0.01	0.09
5	1.125 m Center	0.17	0.01	0.01	0.19
6	1.75 m Center	0.11	0.02	0.14	0.27
7	0.5 m Left	0.08	0.01	0.01	0.10
8	1.125 m Left	0.15	0.01	0.01	0.17
9	1.75 m Left	0.17	0.02	0.10	0.29
				Total	1.48
				9 points Spatial Avg	0.16

Table 24: Percentage (%) of SC6 (including expanded measurement equipment uncertainty only) at each point of the 9-points spatial averaging scheme for location L.

9 points spatial avg	Height (meter)	869 MHz - 894 MHz (% of Safety Code 6 for Uncontrolled Environment)	1930 MHz - 1990 MHz (% of Safety Code 6 for Uncontrolled Environment)	2335.7 MHz-2341.8 MHz (% of Safety Code 6 for Uncontrolled Environment)	Total (% of Safety Code 6 for Uncontrolled Environment)
1	0.5 m Right	0.11	0.03	0.02	0.16
2	1.125 m Right	0.24	0.03	0.01	0.28
3	1.75 m Right	0.31	0.05	0.03	0.39
4	0.5 m Center	0.06	0.01	0.01	0.08
5	1.125 m Center	0.25	0.02	0.01	0.28
6	1.75 m Center	0.31	0.04	0.03	0.38
7	0.5 m Left	0.11	0.02	0.02	0.15
8	1.125 m Left	0.29	0.04	0.01	0.34
9	1.75 m Left	0.31	0.04	0.03	0.38
				Total	2.44
				9 points Spatial Avg	0.27

10. Appendix E: Measurement Scans

This appendix contains samples measurement scans covering the GSM850, GSM1900 and the S-DARS systems.

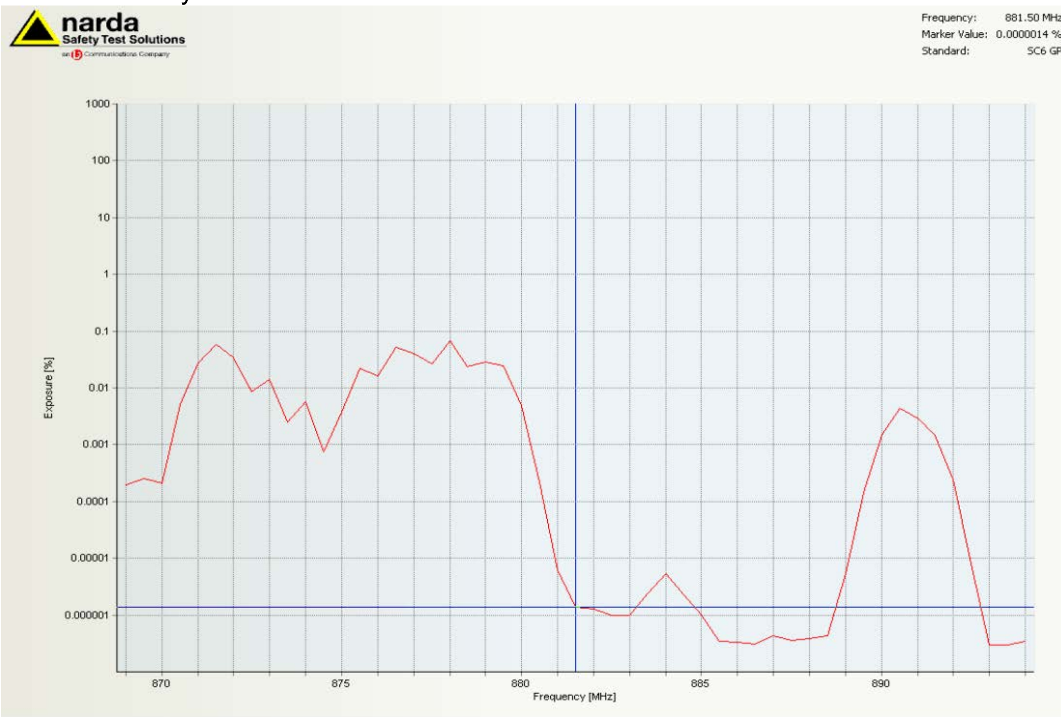


Figure 10: Narda SRM-3000 measurement scan for the frequency range of 869 MHz-894 MHz (GSM 850)

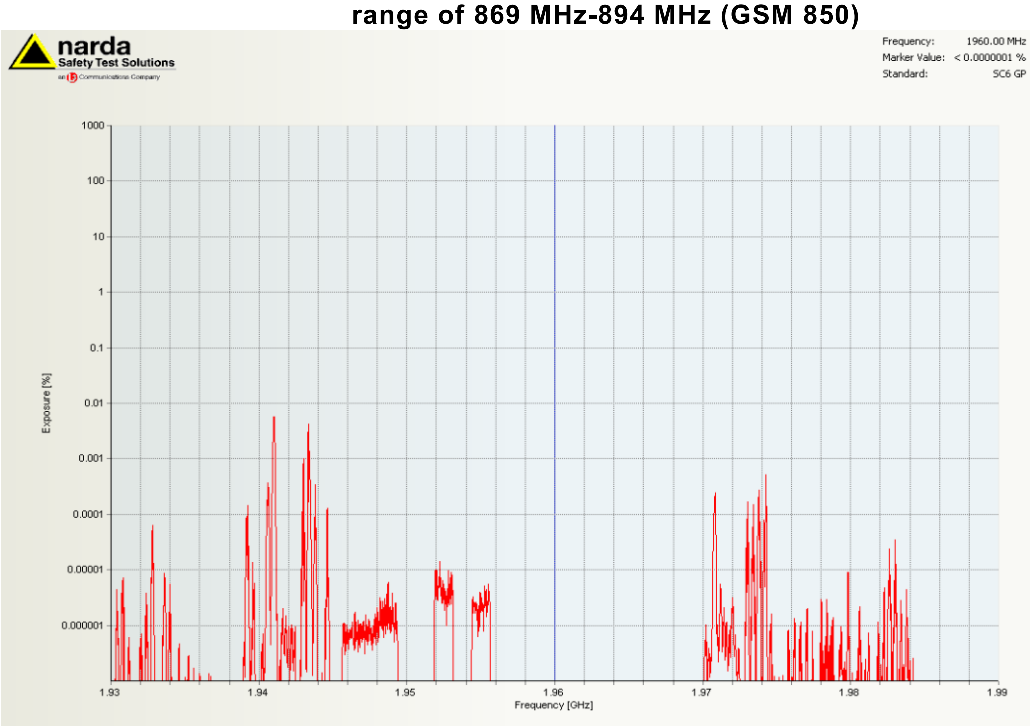


Figure 11: Narda SRM-3000 measurement scan for the frequency range of 1930 MHz-1990 MHz (GSM1900)

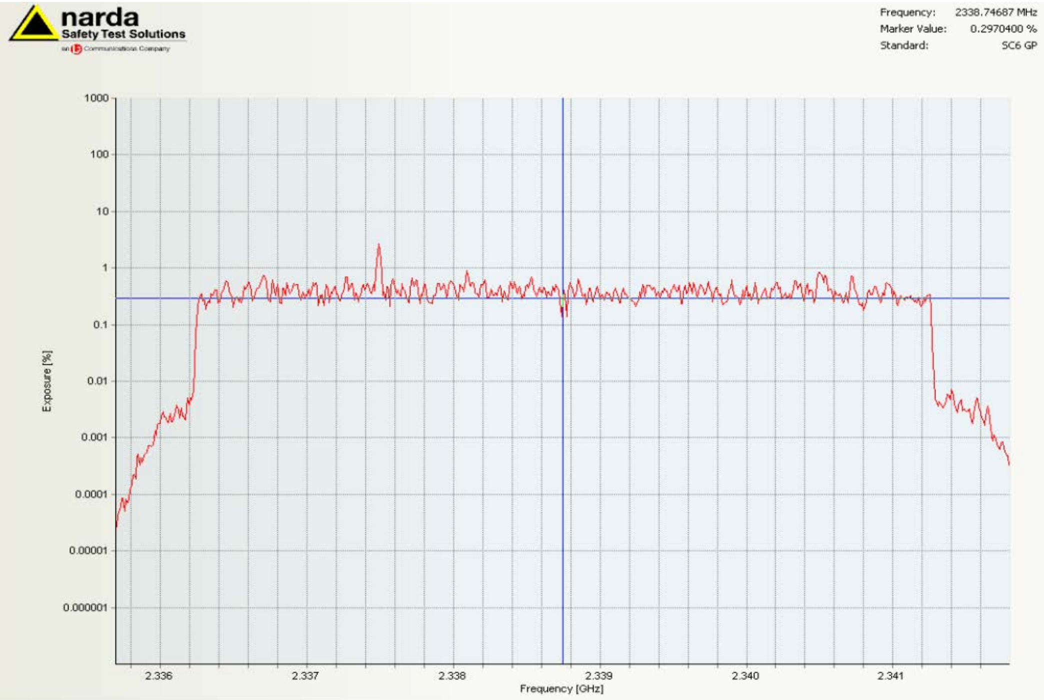


Figure 12: Narda SRM-3000 measurement scan for the frequency range of 2335.8 MHz-2341.4 MHz (S-DARS)

Annex D
(informative)

Roof-top case study with direct access to antennas

This annex contains the Roof-top case study with direct access to antennas, referred to in 4.5. This evaluation report is presented as issued by EMSS Consulting and retains its original structure, formatting, layout and numbering. The standard referred to in the report is IEC 62232.

EMSS Consulting

Evaluation Report

Building, Cape Town, South Africa.

Wessel van Brakel
10 April 2008

Evaluation Report Template

Date of Report: 10 April, 2008	
Title: Macro Base Station Building, Cape Town, South Africa	
Site Location: a building in Cape Town, South Africa	
Site Coordinates (at Antenna): removed	
***Google Earth* Hyperlink:** removed	
Evaluation laboratory: EMSS Consulting Te Deum Building No. 3 Messon Str. Technopark Stellenbosch South Africa	**Company/Client:** Vodacom-SA (Pty) Ltd Vodacom Corporate Park, 082 Vodacom Boulevard, Vodavalley, Midrand South Africa
Evaluation performed by: Dirk Brockman & Wessel van Brakel	**Date of Evaluation:** 2 April 2008 and 9 April 2009
Identification number of original report/s: P00-2008-01 and Evaluation of IEC PT62232 – Spatially Averaged Field on Roof-top – Test Report Draft 01 - 04_2008	
Assessor: Dirk Brockman and Valpre Kellerman EMSS Consulting	**Quality Assurance:** Wessel van Brakel EMSS Consulting

1. Executive Summary

The purpose of this case study was to determine the RF exposure compliance and control boundaries around an operational roof-top macro base station.

The compliance boundary assessment was to determine the area around the base station antennas where the exposure limits are not exceeded, and the control boundary assessment was to determine the location of the physical access controls like barriers and warning signs.

The assessment included on-site spatially averaged field strength measurement at the control boundary and a desktop computational assessment to determine the compliance boundary. The maximum values were compared against international safety guidelines know as ICNIRP (International Commission on Non Ionizing Radiation Protection) Guidelines.

This case study demonstrates that both measurement and computation assessment methods are valid for this type of base station assessment.

An initial visual inspection at the site showed the potential for a significant RF field contribution for other ambient 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 and determined to be 13.2 m from the antennas for the general public limit and 3.2 m from the antenna for the occupational exposure limit.

Spatially averaged field strength measurements were then conducted 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 assessment using a commercial computational tool with ray tracing was conducted, and that determined that the distance from the antenna to general public compliance boundary was less than 10m, and less than 1m 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 not be higher than the relevant ICNIRP limits at the specified control boundary distances. The best estimate assessment scheme was used for both the desktop assessment and field strength measurement.

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

2.1. Site operator information

The test results presented in this report define compliance boundaries for the macro base station situated on a building in Cape Town. The *Vodacom* base station consists of three Kathrein 742241 panel antennas and a single third party unidentified whip antenna. The downlink transmission in the GSM 900 bands was 80 W and UMTS2100 40 W composite power per antenna.

Table 2.1: Operator technology information

Operator	Technology
Vodacom	GSM900, UMTS 2100

2.2. Site environment

Figure 2.2 Photograph of macro cell on building roof-top antenna

As shown in Figure 2.2 the three panel antennas are mounted quite low on the roof-top structure with the whip antenna installed above the roofline.

2.3. Exposure safety limits

The guidelines on limiting exposure, published by the International Commission on Non Ionizing Radiation Protection (ICNIRP), are used as in this report. The ICNIRP guidelines consist of two levels, one for occupational exposure the other for the general public. The purpose of this evaluation is to determine the distance from the antenna to the occupational and general public boundaries.

3. Evaluation Plan: Desktop Computer Modelling (see Clause 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 an appropriate selection of evaluation methods for a given evaluation purpose.

3.1.1. Determine evaluation purpose

Purpose	It is required to identify the exclusion zones by using the reference level limit values as published in the ICNIRP guidelines. The limit should not be exceeded outside the exclusion zones – therefore the highest potential value or the worst case scenario should be used.
Comparison against limit value at specific locations to check if the limit has been exceeded	ICNIRP guidelines could be exceeded at certain locations – inside the exclusion zone determined with IXUS.
Establish boundary against limit value	Compliance boundaries should be established at certain points surrounding the RBS antennas at which the reference level limit values as given in the ICNIRP guidelines is met.

3.1.2. Determine equipment under test (EUT) category

Status to be recorded	
Complex RBS Category	This category is defined since the evaluation needs to consider more than one radiating RBS antenna

3.1.3. Determine physical parameters

The antenna parameters are given in this section. An antenna with an azimuth direction of 0° radiates directly towards the North. A positive electrical tilt means that the antenna is tilted downward.

Antenna 1

Owner	*Vodacom*
Manufacturer	Kathrein 742241
Antenna gain	Determined by IXUS - only the manufacturer and model of antenna given as input
Beam width	Determined by IXUS - only the manufacturer and model of antenna given as input
Orientation	Coordinates of base: (94.6 m; 38.5 m; 24.6 m)
Mechanical Tilt	-1°
Directivity	Azimuth 80°
Dimensions	Determined by IXUS - only the manufacturer and model of antenna given as input from datasheets: Height: 2.628 m; Width: 0.262 m; Depth: 0.149 m
Technology (Air interface)	UMTS and GSM900
Transmit Power	UMTS: 2 ports 20 W each; GSM900: 2 ports 40 W each

Electrical tilt	UMTS: 3°; GSM900: 7°

Antenna 2

Owner	*Vodacom*
Manufacturer	Kathrein 742241
Antenna gain	Determined by IXUS - only the manufacturer and model of antenna given as input
Beam width	Determined by IXUS - only the manufacturer and model of antenna given as input
Orientation	Coordinates of base**:** (94.9 m; 33.3 m; 24.6 m)
Mechanical Tilt	-1°
Directivity	Azimuth 110°
Dimensions	Determined by IXUS - only the manufacturer and model of antenna given as input from datasheets: Height: 2.628 m; Width: 0.262 m; Depth: 0.149 m
Technology (Air interface)	UMTS and GSM900
Transmit Power	UMTS: 2 ports 20 W each; GSM900: 2 ports 40 W each;
Electrical tilt	UMTS: 3°; GSM900: 7°

Antenna 3

Owner	*Vodacom*
Manufacturer	Kathrein 742241
Antenna gain	Determined by IXUS - only the manufacturer and model of antenna given as input
Beam width	Determined by IXUS - only the manufacturer and model of antenna given as input
Orientation	Coordinates of base: (81.1 m; 33.7 m; 24.6 m)
Mechanical Tilt	-1°
Directivity	Azimuth 240°
Dimensions	Determined by IXUS - only the manufacturer and model of antenna given as input From datasheets: Height: 2.628 m; Width: 0.262 m; Depth: 0.149 m
Technology (Air interface)	UMTS and GSM900
Transmit Power	UMTS: 2 ports 20 W each; GSM900: 2 ports 40 W each;
Electrical tilt	UMTS: 3°; GSM900: 7°

3.1.4. Decide if ambient fields are to be considered

In this case, it was not possible to determine the properties of an unknown antenna on the site. The known properties of the antenna are however logged for future reference.

Antenna 4

Owner	Unknown
Type	Looks like a FM or HF Whip
Manufacturer	Unknown
Antenna gain	Unknown
Beam width	Unknown
Orientation	Coordinates of base**:** (96.5 m; 35.3 m; 27 m)
Mechanical Tilt	Unknown
Directivity	Unknown
Dimensions	Height - 3 m; Width - 0.05 m; Depth - 0.05 m
Technology **(Air interface)**	Unknown
Transmit Power	Unknown

A frequency selective measurement is required across the frequency range 75 MHz 3 GHz to establish whether ambient RF levels need to be considered in the assessment.

3.1.5. Establish the evaluation locations required

Evaluations are required everywhere on and just above the roof-top to determine the ICNIRP public and occupational exclusion zones. Environment region M with multiple scatterers/absorbers was defined (see Figure 3.1.5.2). The associated distances of regions I to III were determined and are given in Table 3.1.5.1.

Table 3.1.5.1 Distances and regions

	Region I-M	**Region II-M**	**Region III-M**
Source regions	GSM900: 0…5.2 m UMTS: 0…12.2 m	GSM900: 5.2 m…13.1 m UMTS: 12.1 m… 29.18 m	GSM900: 5.2 m…∞ UMTS: 12.1 m… ∞

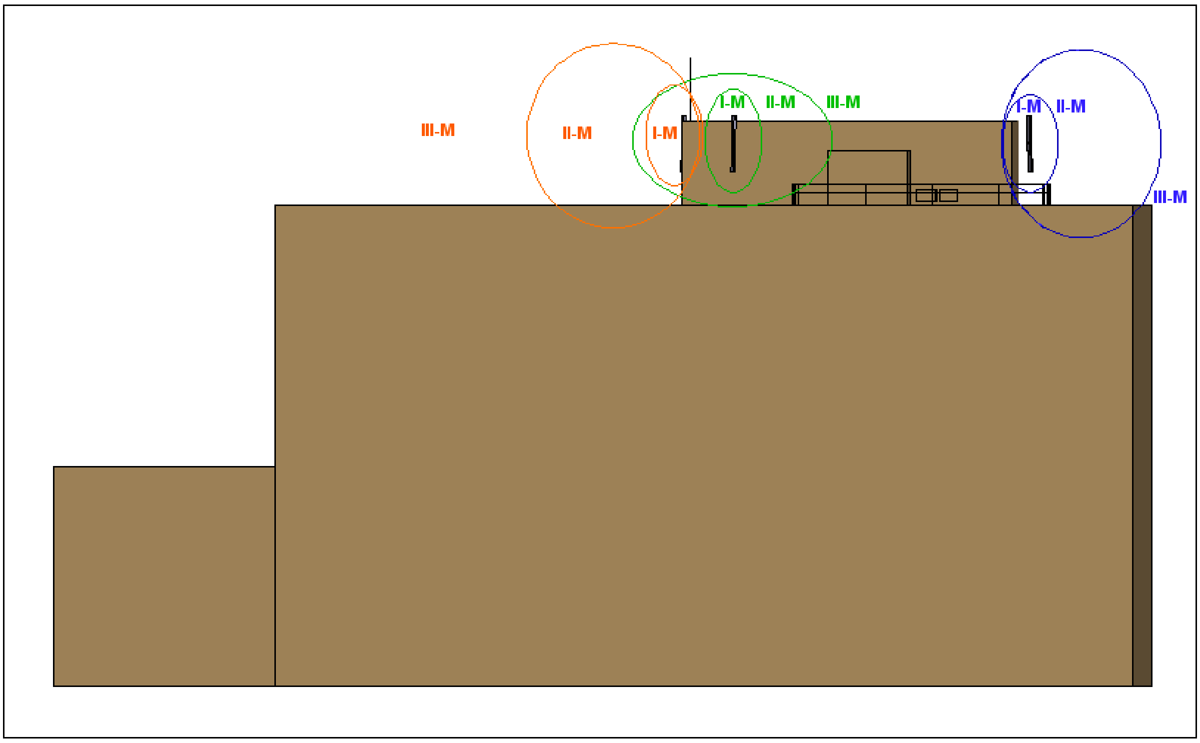


Figure 3.1.5.2 Regions of evaluation on the source environment plane

3.1.6. Estimate the field at the evaluation point

The following basic equation was used at the evaluation points to get an idea of the expected field values at the site:

$$E = \frac{1}{d}\sqrt{30\,\overline{P_{avg}}\,G_i} \quad V/m$$

Where d is the distance from the antenna, P_{avg} is the average power radiated from the antenna and G_i is the gain in that direction.

Estimated field values right in front of each antenna were calculated. The field-values were calculated on the regional boundaries as determined in the previous clause.

For the GSM 900 band:

- Gain of 17 dBi was assumed at 900 MHz (from datasheets)
- Maximum power of 80 W assumed (worst case)

For the UMTS band:

- Gain of 17 dBi was assumed at 2100 MHz (from datasheets)
- Maximum power of 40 W assumed (worst case)

Table 3.1.6 Estimated field vales at various distances from the antennas

Distance from antenna	**Estimated E-field at position due to power emitted in the GSM900 band**	**Estimated E-field at position due to power emitted in the UMTS band**
5.2 m	67 V/m	47 V/m
12.2 m	28 V/m	20 V/m
13.1 m	26 V/m	19 V/m
29.2 m	11.8 V/m	8 V/m

ICNIRP reference levels at 900 MHz is:

- Public - 41.25 V/m
- Occupational – 90 V/m

ICNIRP reference levels at 2100 MHz is:

- Public - 63 V/m
- Occupational – 137 V/m

From the calculated field estimates a distance of 5.2 m in front of each antenna would be inside the public exclusion zone and all other distances calculated would be outside both the public and occupational exclusion zones.

At d = 3.8 m from the antenna the worst case E-field will be 90 V/m (ICNIRP occupational reference level) for GSM 900 band. At d = 1.7 m from the antenna the worst case E-field will be 137 V/m (ICNIRP occupational reference level) for UMTS band.

E-and H-fields cannot be assumed to be orthogonal in region I-M, therefore E- and H-fields should be measured or calculated in this region/s. Also, the far field conditions are not valid in this region and reactive power components are not negligible. This should be kept in mind during site compliance assessments. Furthermore, the E- and H-fields are approximately orthogonal in regions II-M and III-M. Therefore only E- or H-fields needs to be calculated.

3.2. Select evaluation method

The evaluation purpose is to identify an exclusion zone, by calculating the distance where the field values starts to exceed the reference levels.

The ray-tracing (synthetic model) computational method will be employed since it is the simplest method to achieve the evaluation purpose. Numerical simulation can be performed in this case since the characteristics of the sources are well defined. The frequencies, transmitter power, antenna characteristics, height of antenna, etc are all known.

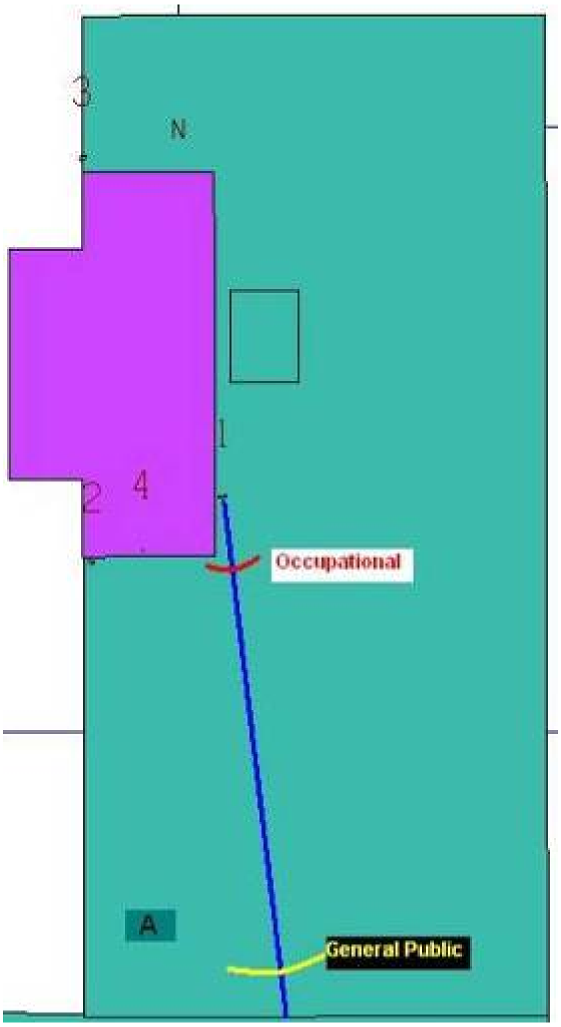
The evaluation method chosen is appropriate for the required solution and the assessor has suitable computational resources to do the evaluation and access to the IXUS Modeller which is an implementation of the ray-tracing (synthetic model) computational method.

4. Evaluation Plan: Spatially Averaged Field Strength Measurement (see Clause 5.1, 5.2 & Annex A.)

4.1.1. Determine evaluation purpose

It is required to find, on the sector line of Antenna 1 (see Figure 4.1.1) on the roof-top of the Good Hope cellular base station, the positions of the boundaries of the ICNIRP General Public and Occupational Compliance Zones. It is also required to determine a typical parameter value as part of post processing at Position A.

Figure 4.1.1: Site Plan



4.1.2. Determine equipment under test (EUT) category

For the case at the ICNIRP occupational control boundary, the equipment under test is categorized as Simple RBS, as the received power contribution from Antenna 1 should dominate. The equipment under test is categorized as Complex RBS for the other two positions, as both antennas 1 and 2 should contribute to the received power. The physical parameters for the relevant antennas on the site are summarized in Table 4.1.3:

4.1.3. Determine physical parameters

Table 4.1.3: Physical parameters of relevant antennas (#1 and #2)

Antenna Type and Model	**Kathrein Dual Polarized Tri-Band A-Panel (742241)**
Gain [dBi]:	
824 – 960 MHz	17
1710 – 2170 MHz	17
Half-power Beam Width [°]	65
Orientation	Vertically mounted
Directivity	
Dimensions:	
Height [m]	2.628
Width [m]	0.262
Depth [m]	0.149
Technology	
Frequencies	GSM (935.1 – 946.1 MHz) & UMTS (2110 – 2125 MHz)
Transmit Power	GSM (80W max) & UMTS (40W max)

4.1.4. Decide if ambient fields are to be considered

Ambient fields at the ICNIRP occupational control boundary do not need to be included in the evaluation as the contribution to the Total exposure should be dominated by antenna 1. Ambient fields at the ICNIRP general public control boundary and at Position A will be included in the evaluation, but only if those fields are not less than 20 dB below the maximum field strength from the RBS antennas. The source environment plane regions for the roof-top antennas are shown in Figure 4.1.5. The distances are determined as follows:

Region I: $0 \cdots max\begin{pmatrix} \lambda \\ D \\ \frac{D^2}{4\lambda} \end{pmatrix} \rightarrow 0 \cdots max\begin{pmatrix} 0.32m \\ 2.628m \\ 5.40m \end{pmatrix}$

Region II: $max\begin{pmatrix} \lambda \\ D \\ \frac{D^2}{4\lambda} \end{pmatrix} \cdots max\begin{pmatrix} 5\lambda \\ 5D \\ \frac{0.6D^2}{\lambda} \end{pmatrix} \rightarrow max\begin{pmatrix} 0.32m \\ 2.628m \\ 5.40m \end{pmatrix} \cdots max\begin{pmatrix} 1.6m \\ 13.14m \\ 12.95m \end{pmatrix}$

Region III: $max\begin{pmatrix} 5\lambda \\ 5D \\ \frac{0.6D^2}{\lambda} \end{pmatrix} \cdots \infty \rightarrow max\begin{pmatrix} 1.6m \\ 13.14m \\ 12.95m \end{pmatrix} \cdots \infty$

4.1.5. Estimate the field at the evaluation point

Through experience with research and many roof-top measurements close to RBS antennas it is noticed that the conservative approach for the distance from the antenna for the boundary between regions I and II of $\frac{D^2}{4\lambda}$ is not valid for these type of panel antennas, but rather the value of D_{max} is used.

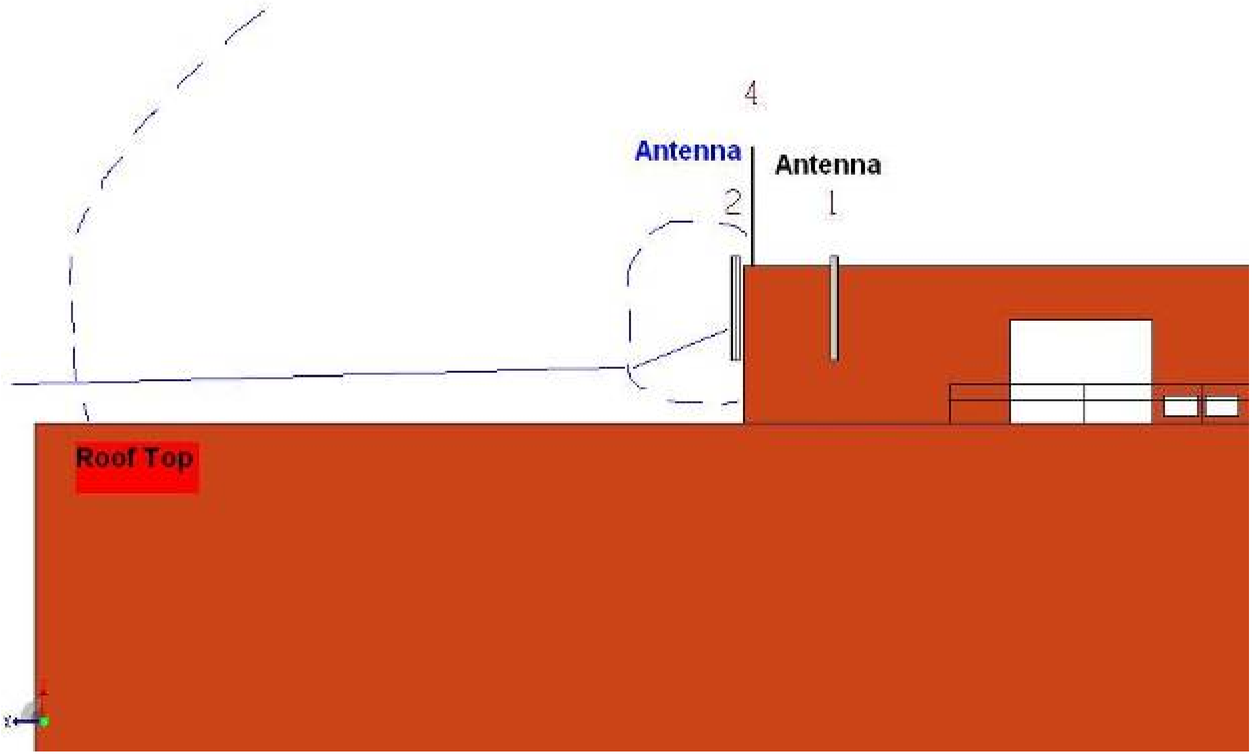


Figure 4.1.5: Source Environment Plane Regions near Roof-top Antenna 2

The field at the evaluation point for the Occupational Boundary should not exceed

$$E = \frac{1}{d}\sqrt{30 \cdot \bar{P}_{avg} \cdot G_i} \ \frac{V}{m}$$

$$= 131.92 \text{ V/m}$$

Further, the field should not exceed 45.80 V/m at the General Public Boundary on the sector line of Antenna 1. These field values were determined by making use of the maximum possible power being transmitted, and using the maximum gain available from the antenna, even though the evaluation points are quite below and/or away from the main beam of the antennas. The spatial average E-field at the evaluation points are to be evaluated and compared to the ICNIRP Boundary levels.

The evaluation method to be used at the occupational and general public boundary measurement positions is spatially averaged field to establish the boundary against limit value. For position A, a typical value as information is to be evaluated through spatially averaged field measurements.

4.1.6. Establish the evaluation locations required

Figure 4.1.6 shows the environment on the roof-top where the measurements were to be performed.

Figure 4.1.6: Roof-top environment

The positions on the sector line of Antenna 1 where the ICNIRP zones should be present were determined from known simulation results to be 3.22 m and 13.10 m from Antenna 1's front surface, on the sector line, while position A were determined through the handheld field measurement techniques to be a position where the contribution from both antennas 1 and 2 were roughly the same in field strength, 9.48 m perpendicular from the wall Antenna 2 is mounted on, 1.28 m from the corner between Antennas 1 and 2. All measurements subsequently performed at these measurement positions were performed with the probe of the measuring system mounted on a non-conductive tri-pod.

4.2. Select evaluation method

Frequency selective measurements over a broad bandwidth (75 MHz – 3 GHz) were performed at each position to determine if other EMF sources should be included in the evaluation. Although a DCS contribution was observed, it was more than 20 dB below the maximum field strength observed, thus only GSM and UMTS contributions were included within the evaluations.

Frequency selective measurements within the GSM and UMTS bands were performed to determine the maximum field strength of the pilot channels from each antenna at each frequency band. Spatial averaging over 9-points was used at each measurement position. Figure 4.2 below shows the setup at each Measurement Position.

Figure 4.2 Measurement setups at different measurement positions

4.3. Complete the evaluation plan

Develop check sheet to be used on site

Table 4.3.1 Check sheet to be used on site:

Task	Check
Observe working place for any unsafe threats	
Determine measurement positions exact locations	
Determine different frequency contributors at all measurement positions	
Measure each frequency band of interest at all measurement positions	
Perform spatial averaging measurements at all measurement positions	
Download data to laptop before leaving site	

Table 4.3.2 Risk assessment for working on roof-top RBS sites:

Hazard	Severity	Precautions
Over exposure by RBS antennas	4	RF Training to all personnel working on roof-tops
Dehydration and Heat Stroke	8	Wear Hat and drink enough water/fluids while working on roof-top
Fall off roof	5	Clear communication to all personnel to keep away from roof edges
Injuries on roof	2	Proper observation and safe working procedures in place

Risk Severity = Probability (1 [almost no chance] – 5 [will happen]) x Seriousness (1[not serious] – 5[life threatening])

5. Results (see Clause 8 of the Standard)

5.1. Results summary- desktop computer modelling

The benefit of computational modelling is that the entire general public and occupational zones can be calculated and displayed. The figures below depict such zones predominately in plan (top) and elevation views (cross section from the side). Table 5.1.1 details the zone colours and types of personnel permitted in such areas.

Table 5.1.1: Meaning of exclusion zone colours.

Red Zone	No access without following appropriate shut-down, power-down or pass-through procedures.
Yellow Zone	Access only allowed for RF trained personnel. No access for general staff, maintenance personnel or the public.
Transparent Zone	Accessible for public.

.

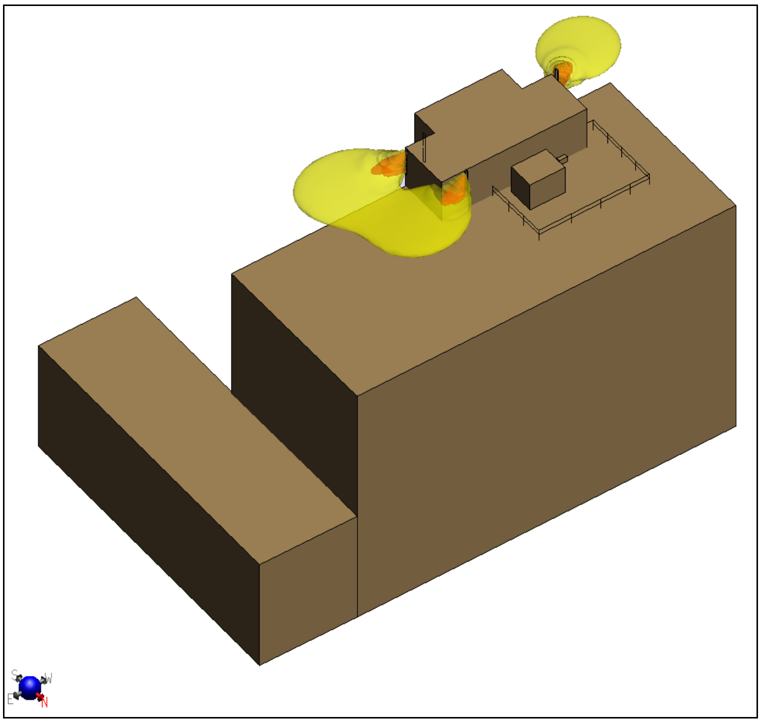


Figure 5.1.2: Public and occupational exclusion zones calculated with IXUS

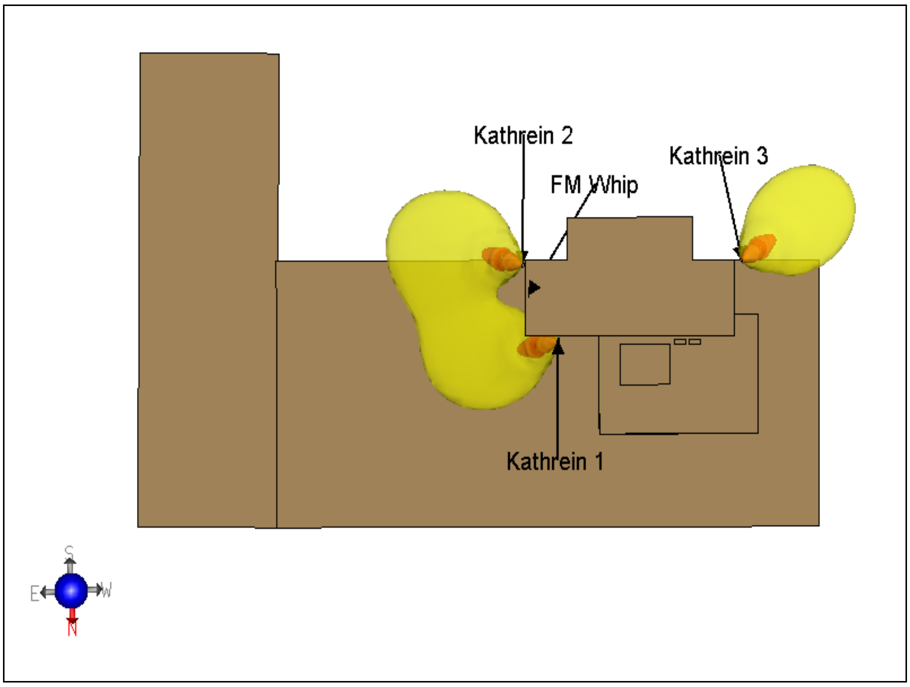


Figure 5.1.3: Top view of exclusion zones and building.

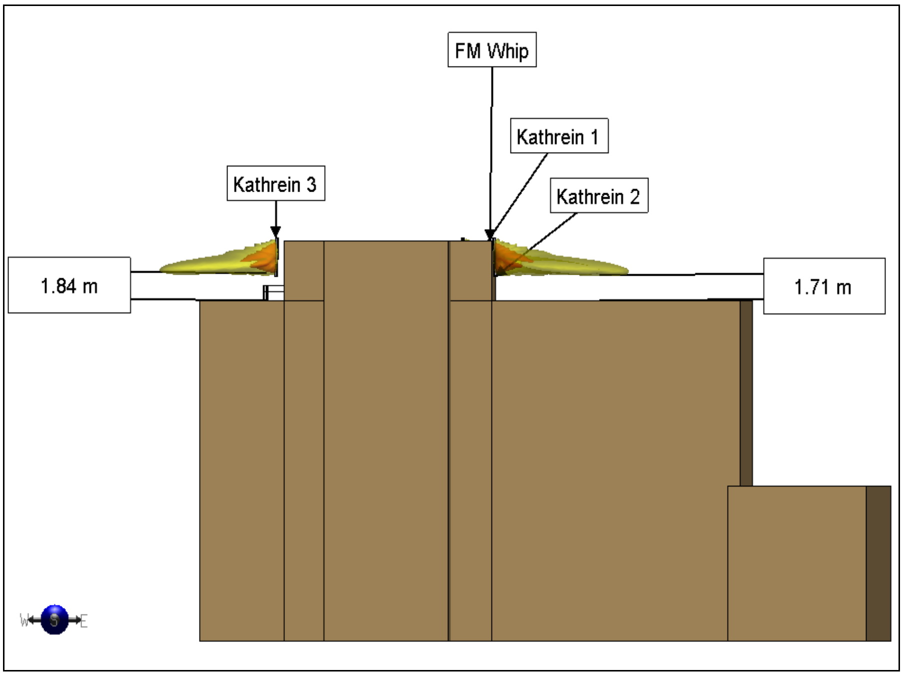


Figure 5.1.4: View exclusion zones from south side of building.

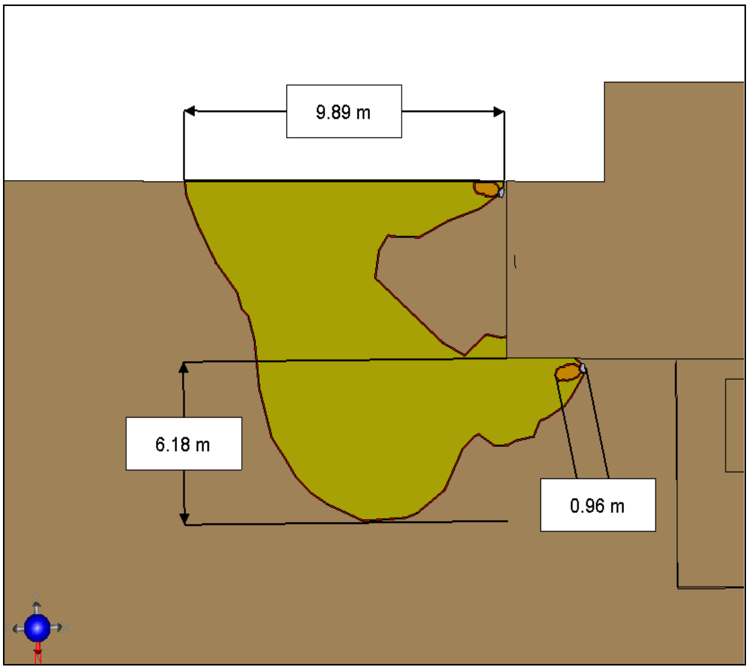


Figure 5.1.5: Top view - public and occupational caution lines surrounding antennas Kathrein 1 and 2.

The public zones in the vicinity of antennas 1 and 2 (Kathrein 1 and 2) reaches up to 9.89 m from the wall behind Kathrein 2 and 6.18 m from the side wall behind Kathrein 1. The occupational exclusion zones reaches up to 0.96 m in front of each antenna. The exclusion zones in front of Kathrein 3 were calculated at 0.32 m from the antenna to the occupational boundary, and 2.89 m from the antenna to the general public boundary, remembering that most of the exclusion zones from this antenna are over the edge of the building (see figure 5.1.3).

Further graphical results can be found in Appendix D of this report.

5.2. Results summary- spatially averaged field strength measurement

The results (each antenna's, as well as Total contribution) obtained after extrapolation and spatial averaging post-processing is shown in Table 5.2 below.

Table 5.2: Total Contribution at Measurement Positions (% of Limit Value)

Measurement Position	Limit Value	Total Contribution	Contribution from Antenna 1	Contribution from Antenna 2
Occupational Line (3.22m)	% of ICNIRP Occupational	15.79	15.50	0.29
General Public Line (13.1m)	% of ICNIRP General Public	54.52	48.15	6.37
Position A	% of ICNIRP General Public	15.02	7.44	7.59

The maximum field strength observed at each measurement position while doing spatial average was 23.16 V/m at the Occupational Boundary position, 17.77 V/m at the General Public Boundary position, and 8.48 V/m at Position A.

5.3. Uncertainty Analysis – interpretation of results (see Clause 8 and Annex M of the Standard)

The RF output power used in the desktop computational and the extrapolation factors applied to the field strength measurements reflect the condition when the RBS is operating at its theoretical maximum RF output power. Considering that this is an abnormal operating condition and that there is only limited access to the roof-top, the best estimate assessment scheme (Table M.1, Case 1) is considered acceptable.

Desktop Computational Assessment - The desktop assessment determined that the distance from the antenna to the general public compliance boundary was approximately 10 m, and approximately 1 m to the occupational compliance boundary.

The desktop computation assumes no RF feeder or transmission system loss for the calculation of maximum field strength. A correction factor of -3.5dB is specified in the uncertainty table (annex A table 7.1) to account for typical feeder and transmission system losses. This means that the results of the desktop simulations would be up to 3.5 dB (2.2 times) less than the ICNIRP limits when including the feeder or transmission loss.

- The desktop computation uncertainty analysis presented in Annex A Table 7.1 gives an expanded uncertainty of 7.22dB (CI 95%). This means a possible variation in level of + 5.3 times.

- When you consider the expanded uncertainty 7.22 dB with the correction factor of -3.5 dB, the overall assessment is within a typical uncertainty range for desktop simulations

Field Strength Measurement - The measured RF field strength data was assessed to establish the confidence that the relevant ICNIRP limits are not exceeded at the occupational control boundaries (3.22 m) and general public control boundary (13.1 m). The measurement uncertainty analysis presented in Annex A Table 8.1 gives an expanded uncertainty value of 4.05 dB (2.54 times) (CI 95%) with a combined correction factor of 0 dB.

- For the occupational control boundary at 3.22 m, the best estimate field strength is 15.8% of the limit. Increasing this value by the expanded uncertainty (2.54 times) gives a value of 40.1% of the limit – i.e. 97.5% probability that the true level is below 40.1% of the limit. This means that there is more than 97.5% probability that at the designated occupational control boundary the true value will be below the limit.

- For the general public control boundary at 13.1 m, the best estimate field strength is 55% of the limit. Increasing this value by the expanded uncertainty (2.54 times) gives a value of 140% of the limit. i.e. 97.5% probability that the true level is below 140% of the limit. A quick estimate (also look at Fig O.1 of the standard) shows that there is about 90% probability that at the designated general public control boundary the true value will be below the limit.

The compliance boundaries determined from the desktop computation and control boundaries determined from the field strength measurement fulfil the requirements of the selected best estimate assessment scheme in that there is more than 50% probability that the true RF field strength is below the relevant ICNIRP limit value.

6. Conclusions

The desktop computational assessment 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.

To be conservative a general public exposure limit control boundary was chosen to be 13.2 m from the antennas and the occupational exposure limit control boundary was chosen to be 3.22 m from the antennas.

Spatially averaged field strength measurements were conducted on the roof-top at the control boundary distances of 13.2 m and 3.22 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

This case study demonstrates that both measurement and computation assessment methods are valid for this type of base station assessment.

In this specific example, the compliance control boundaries have been set in accordance with the on-site measurements. In accordance with Annex A of the IEC Standard (Table A.7: Evaluation method ranking) the E field measurement results takes precedence over the E field ray tracing computed results. The measurement results have demonstrated a conservative assessment and validate the computation results.

7. Appendix A (Evaluation Report): Uncertainty Analysis Desktop Computer Modelling (see Clause 7 and Annex O of the Standard)

All the quantities that may reasonably be expected to cause significant variation or uncertainty in the evaluation were identified and are shown in Table 7.1.

While determining the dimensions of the site during an on-site visit by EMSS personnel, all reasonable efforts were made to measure everything as accurately as possible. It is expected that the maximum error made when determining the position of the antenna is not more than 20 cm and the maximum error made when determining the direction of the antenna is not more than 10 degrees. In view of this, the uniform uncertainty in output power density of the antenna positioning and mounting and support structure is considered to be negligibly small and was omitted.

Table 7.1 Uncertainty Assessment for Desktop Computation

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
System									
Variation in the radiated power of the RF source	Transmitter power can vary.	dB	Rect	2	1.73	1	0	1.15	1.33
Cable and system losses	Long cables connect the transmitters to the antennas.	dB	Rect	1.75	1.73	1	-2.25	1.01	1.02
Radiation Loss	Lossy components inside antennas cause radiation loss.	dB	Rect	1.25	1.73	1	-1.25	0.72	0.52
Technique Uncertainties									
Near-field Model Uncertainty	Simplicity of antenna models and the method for determining model parameters limit the accuracy of field predictions.	dB	Rect	3	1.73	1	0	1.73	3.00
Environmental Uncertainties									
Reflection and Scattering	Scattering and reflections on top of buildings can create hotspots where E-fields add in-phase.	dB	Rect	4.8	1.73	1	0	2.77	7.68
Combined correction factor, $t_c = \sum_{i=1}^{N} t_i$									**-3.50**
Combined standard uncertainty, $u_c = \sqrt{\sum_{i=1}^{N} (c_i^2\ u_i^2)}$									3.68
Coverage factor for 95% CI, k									1.96
Expanded Uncertainty, $U = k * u_c$									**7.22**

8. Appendix B (Evaluation Report): Uncertainty Analysis Spatially Averaged Field Strength Measurement (see Clause 7 and Annex O of the Standard)

The uncertainty estimate for the measurements performed is shown below in Table 8.1.

Table 8.1: Uncertainty assessment for measurements performed

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									
Calibration (including meter level, antenna factor, antenna factor interpolation, variation due to frequency response of probe/meter, cable loss, mismatch, noise and power chain uncertainties)	Manufacturer calibration certificate values used, Verified at accredited calibration lab within 1dB Measurement Uncertainty	dB	normal	1.5	1.96	1	0	0.77	0.586
Combined linearity deviation of the meter / cable / antenna	Manufacturer's data sheet: 25 Frequency points through complete f range, measurement range settings -27 -> 23 dBm	dB	Rect	0.17	1.73	1	0	0.10	0.010
Isotropy of the antenna	Ellipse Ratio according to Manufacturer's data sheet	dB	rect	1.27	1.73	1	0	0.73	0.538
Combined temperature and humidity response of meter / cable / antenna	Within temperature range of Manufacturer's data sheet	dB	rect	0	1.73	1	0	0.00	0.000
Methodology									
Probe position in high field gradients	Not applicable - test positions not in high field gradients	dB	rect	0	1.73	1	0	0.00	0.000
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	No analog meter reading – results stored automatically to memory for download to pc	dB	triang	0	2.45	1	0	0.00	0.000

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
Source and environment									
Spatial Averaging	Averaged uncertainty with a 95 % confidence interval for a 9-point grid as per CENELEC	dB	rect	1.8	1.73	1	0	1.04	1.080
Variation in the power of the RF source from the nominal level	Datasheet of radio manufacturer states Output Power uncertainty to be +- 2 dB	dB	rect	2	1.73	1	0	1.15	1.333
Field reflections from movable large objects near the source during measurement	No moving large objects	dB	rect	0	1.73	1	0	0.00	0.000
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, $u_c = \sqrt{\sum_{i=1}^{N} (c_i^2\ u_i^2)}$									2.07
Coverage factor for 95% CI, *k*									**1.96**
Expanded Uncertainty, $U = k * u_c$									**4.06**

9. Appendix C (Evaluation Report) – Equipment List

9.1. Equipment list - desktop computer modelling

The site was assessed using IXUS version 2.8.10, Calculator 4.7, 2008-04-03.

9.2. Equipment list - spatially averaged site field strength measurement

NARDA Selective Radiation Meter (SRM-3000) with tri-axial probe and 2 m RF Extension Cable. Spectrum measurements were done and data stored in dbV/m, while UMTS data from demodulation mode were measured and stored in V/m.

10. Appendix D (Evaluation Report) – Desktop Modelling Results

The site was Assessed using IXUS version 2.8.10, Calculator 4.7, 2008-04-03. In addition to the graphics shown in clause 4.1 of this document, Figures 10.1 and 10.2 below detail the occupational and general public zones for the building roof-top.

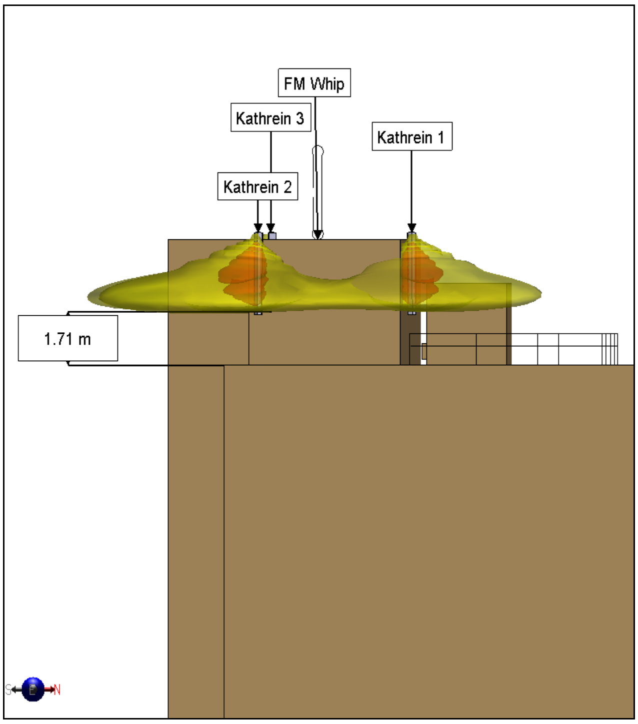


Figure10.1: View exclusion zones from east side of building.

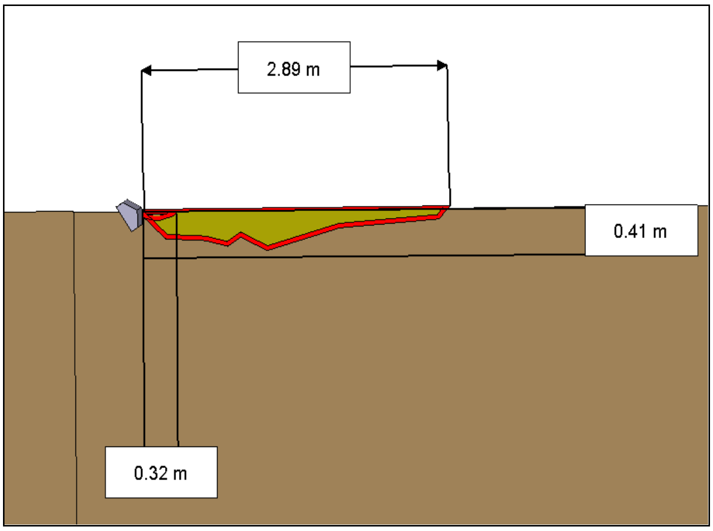


Figure 10.2: Top view. Public and occupational caution lines surrounding antennas Kathrein 3

11. Appendix D: Validation of Commercial Modelling Code

In this appendix the validation of the commercial EME modelling application *IXUS* is presented.
The commercial code that was chosen to do the compliance assessment with is IXUS. This code was validated against the values given in IEC 62232, Annex E.3 by the IXUS developers. The validation figures, as supplied by them, are given in this section.

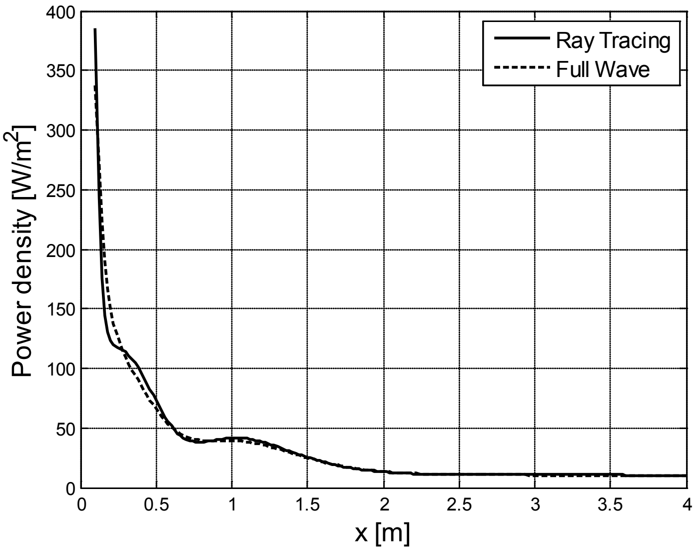


Figure 11.1: Power density comparison along line 1.

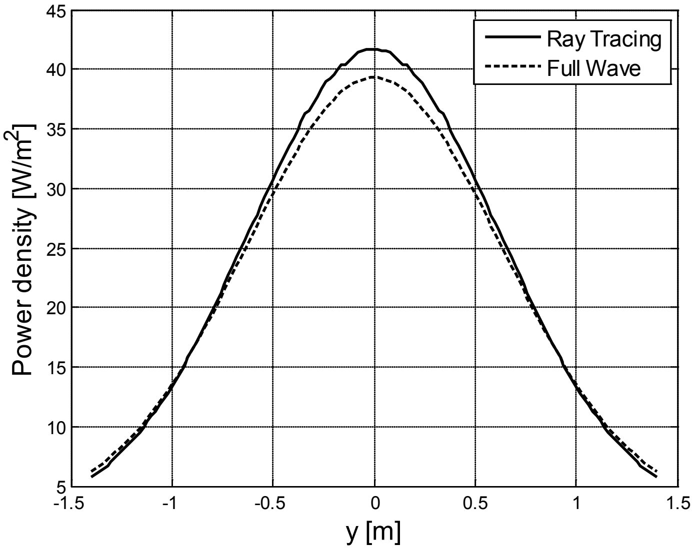


Figure 11.2: Power density comparison along line 2.

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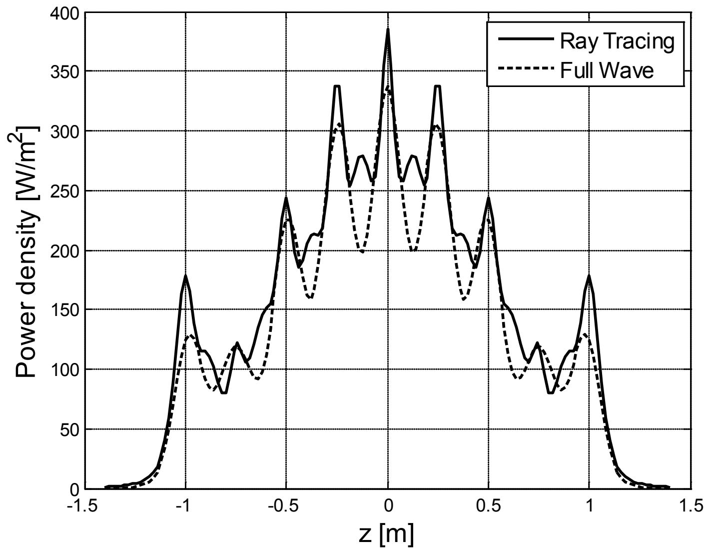


Figure 11.3: Power density comparison along line 3

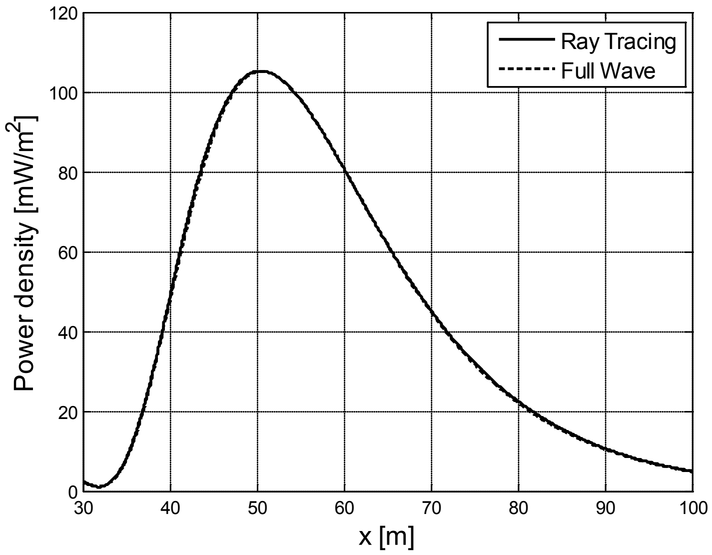


Figure 11.4: Power density comparison along line 4.

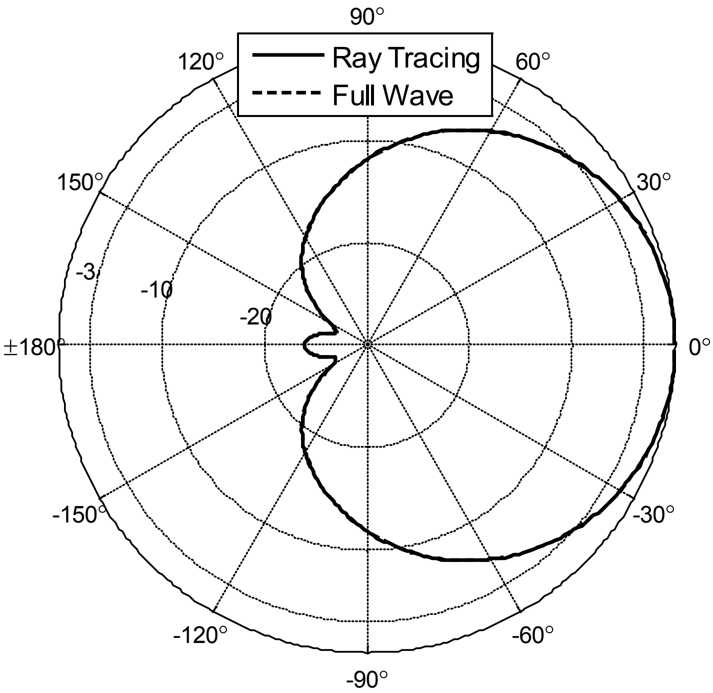


Figure 11.3: Horizontal far-field radiation pattern comparison.

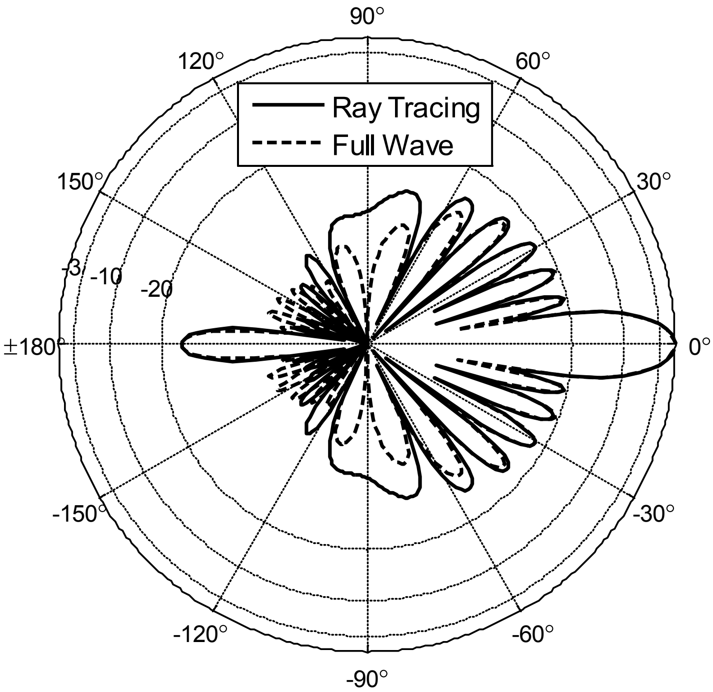


Figure 11.4: Vertical far-field radiation pattern comparison

Annex E
(informative)

Roof-top case study with no direct access to antennas

This annex contains the roof-top case study with no direct access to antennas, referred to in 4.6. This evaluation report is presented as issued by NTT Docomo, Inc. and retains its original structure, formatting, layout and numbering. The standard referred to in the report is IEC 62232.

NTT DOCOMO, INC

Evaluation Report

Isehara-chou Isehara-city Kanagawa pref., Japan

Yoshiaki Tarusawa
6/1/2008

Evaluation Report Template

Date of Report: 1st June, 2008	
Title: Assessment of RF exposure level from roof-top mobile base station	
Site Location: Isehara city Kanagawa pref., Japan	
Site Coordinates (at Antenna): removed	
***Google Earth* Hyperlink:** removed	
Evaluation laboratory: Research Laboratories NTT DOCOMO, INC. 3-6 Hikarino-oka, Yokosuka-shi, Kanagwa, 239-8536, Japan	**Company/Client:** Network department NTT DOCOMO, INC. 2-11-1 Nagata-chou, Chiyoda-ku, Tokyo, 100-6150, Japan
Evaluation performed by: Junji Higashiyama	**Date of Evaluation:** 2008-03-10
Identification number of original report: docomo R&D No. 20-067	
Assessor: Junji Higashiyama Research Engineer higashiyamaj@nttdocomo.co.jp Tel +81 46 840 3711	**Quality Assurance:** Yoshiaki Tarusawa Executive Research Engineer tarusawa@nttdocomo.co.jp Tel +81 46 840 3502

1. Executive Summary

This case study is the evaluation of 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 assessment involved frequency selective measurements of the radio base station control channels and extrapolation for maximum operating power.

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 conducted 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 the target uncertainty was met.

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

2.1. Overview

This case study shows compliance to the basic restrictions related to human exposure to radio frequency electromagnetic fields, on the roof-top of a building where a mobile radio base station is installed. After developing an evaluation plan, the electric field is measured using the spatial averaging technique when the base station handles actual radio access calls. The measurement results show that the total exposure ratio is less than the limits under the condition of maximum traffic at the foot of the antenna mast.

The antenna system of a mobile base station can be mounted on an antenna tower or established on the roof-top of a building of a business or residence. On a roof-top, it is possible that the general public may come into close proximity to the base station antenna mast. After the base station begins operation, the base station designer or mobile service operator is often requested to demonstrate compliance to the guidelines for human exposure to radio frequency electromagnetic fields excited from a base station antenna.

2.2. Site operator information

The base station evaluated in this report is operated by NTT DOCOMO. INC, and is located in Isehara city, which is a typical Japanese sub-urban environment.

Table 2.2: Operator technology information

Operator	Technology
NTT DOCOMO, INC.	PDC 800, PDC 1500, UMTS 2100

2.3. Site environment

Figure 2.3 Photograph of base station on building roof-top

The macrocell installation consists of a number of antennas spread around the perimeter of the lift motor room/stairwell of the building. The transmitting frequency covers the 800 MHz, 1500 MHz, and 2100 MHz-bands for the both 2nd generation and 3rd generation mobile communication systems. The radio base station consists of multiband antennas in a three sector configuration. The distance from the roof-top to the bottom of the antennas is 7 m.

2.4. Exposure safety limits

The exposure limits for this evaluation are derived from Article 21 (iii) Paragraph 3 of the Regulations for Enforcement of the Japanese Radio Law. The electric field strength reference levels are harmonised to the ICNIRP Guidelines. The reference levels from Article 21 are listed in Table 2.4.

Table 2.4 Reference levels of radio law regarding mobile base station environments

Frequency	Electric field strength [V/m]	Magnetic field strength [A/m]	Power density [mW/cm^2]	Averaging time [minute]
30MHz-300MHz	27.5	0.0728	0.2	6
300MHz – 1.5MGHz	1.585 $f^{1/2}$	$f^{1/2}$/237.8	f/1500	
1.5GHz – 300GHz	61.4 V/m	0.163	1	
Note; The unit of frequency f is [MHz].				

3. Evaluation Plan (see Clause 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 an appropriate selection of evaluation methods for a given evaluation purpose.

3.1.1 Determine evaluation purpose

The purpose of this assessment is to demonstrate compliance with human exposure limits for a roof-top-installed mobile base station.

3.1.2 Determine equipment under test (EUT) category

The mobile base station as the target radio source is categorized as a "Complex RBS," which enables co-operation with 2nd and 3rd generation digital mobile systems.

3.1.3 Determine physical parameters

The mobile base station as the target radio source is categorized as a "Complex RBS," which enables co-operation with 2nd and 3rd generation digital mobile systems. Table 3.1.3 summarizes the physical parameters of the mobile base station. The transmission frequencies for the PDC system as the 2nd generation and the IMT-2000 as the 3rd generation system co-exist in the 800 MHz band, 1.5 GHz band, and 2 GHz band. Figure 3.1.4.1 shows the physical relationship of the antenna system and the roof-top of the building. The antenna system generates a sector radio zone and comprises three antennas mounted on masts. The antennas are based on vertical dipole linear array antennas, and are commonly used in the 800 MHz band, 1.5 GHz band, and 2 GHz band. The height from the roof-top to the bottom of the antenna is 7 m.

Table 3.1.3 Physical parameters for RBS as target radio source

	Values		
Frequency band	800 MHz	1.5 GHz	2 GHz
Wireless system	PDC	PDC	UMTS(W-CDMA)
Number of sectors	3	3	3
Maximum RBS RF power	72 W/sector	16 W/sector	16 W/sector
Feeder loss	3	4	5
Matching loss (VSWR)	< 1.2	< 1.2	< 1.2
Number of transmitters or Power ratio	Number of transmitters 18/sector	Number of transmitters 4/sector	Power ratio 8 X 3 (each sector)
Type of antenna	Linear array	Linear array	Linear array
Horizontal half power beam width of antenna	120 degree	120 degree	120 degree
Maximum gain of antenna	17 dBi	18 dBi	20 dBi
Largest dimension of antenna	5.5 m	5.5 m	5.5 m

3.1.1 Decide if ambient fields are to be considered

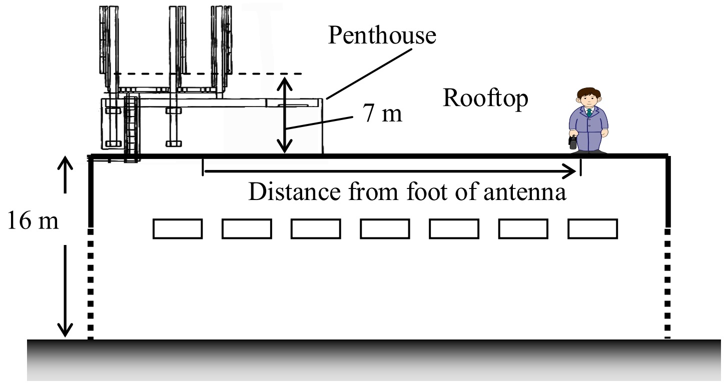


Figure 3.1.4.1 Antenna system of mobile base station installed on building roof-top

This evaluation is intended only to establish the exposure from the target radio source based on the physical parameters. Therefore, evaluating the total exposure is not required with respect to other radio sources including other mobile base stations and broadcast transmission sites.

However, visible inspection and wide frequency spectrum measurement were performed on the roof-top of the building, to verify that critical conditions are not found.

Based on visible inspection, several mobile base stations are identified to be at a distance of more than approximately 2 km from the target source. At the transmission site, TV, FM radio broadcasts, and medium wave radio broadcasts were not identified on the roof-top. Figure 3.1.4.2 shows the measured frequency spectrum at the roof-top using a spectrum analyser and the isotropic broadband antenna, in the frequency range from 30 MHz to 3 GHz. The peak value of the electric field is 120 dBμV/m at the frequency of approximately 1500 MHz, and the total exposure ratio, which is weighted with the exposure limit as a function of the frequency, is 0.04%. Based on visible inspection and the spectrum measurement, the roof-top environment does not present critical exposure conditions even if the field strength from the base station on the roof-top has a time variation according to the radio traffic.

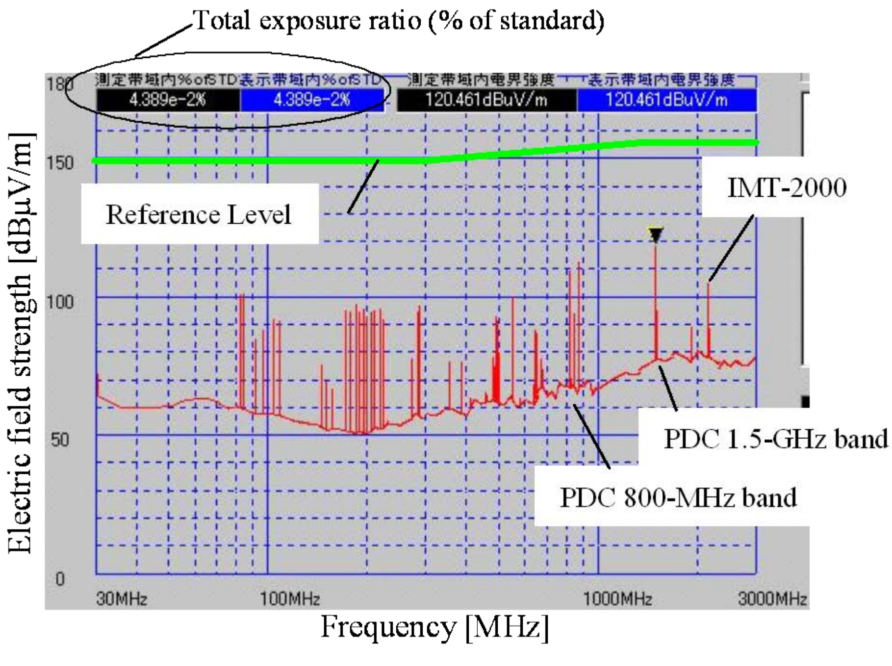


Figure 3.1.4.2 Example of frequency spectrum measured on roof-top

3.1.5 Establish the evaluation locations required

The vertical linear array antenna used in this base station has the largest dimension of 5.5 m. Table 3.1.5 shows the calculated distance related to the boundary of the source-region. In this case, the boundary between Source-Regions I and II is 0.09 m and 0.04 m at the frequency of 800 MHz and 2 GHz, respectively. The boundary between Source-Regions II and III is 161 m and 423.3m at the frequency of 800 MHz and 2 GHz, respectively. The distance from the foot of the antenna mast to the far edge of the roof, is approximately 15 m. The shortest distance between the bottom of the antenna and the head of a human is approximately 5 m when a human is standing just under the antenna. Therefore, the roof-top environment is categorized as a Source-Region II, which is a radiated near field area.

On the other hand, the antenna is directly visible on the roof-top. It is possible that a penthouse or roof-top based on a concrete structure causes scattering phenomena with respect to the radio propagation. Based on these views, the roof-top is categorized as Environment-Region 0 or 1, which indicates no scatter or one reflector.

Table 3.1.5 Distance of boundary related to source region

Frequency	λ [m]	$\lambda/4$ [m]	$\frac{2L^2}{\lambda}\sin^2\beta + \frac{L}{2}\cos\beta$	1.6λ $(L_{end} < 0.3\lambda)$	$5L_{end}$ $(0.3\lambda \le L_{end} \le 2.5\lambda)$	$\frac{2L_{end}^2}{\lambda}$ $(L_{end} \ge 2.5\lambda)$
800 MHz band	0.37	0.09	161.0 ($\beta=\pi/2$) 2.7 ($\beta=0$)	0.6	0.5	0.1
1.5 GHz band	0.20	0.05	295.5 ($\beta=\pi/2$) 2.7 ($\beta=0$)	0.3	0.5	0.1
2 GHz band	0.14	0.04	423.3 ($\beta=\pi/2$) 2.7 ($\beta=0$)	0.2	0.5	0.2
In this case, L is the antenna largest dimension of 5.5 m and L_{end} is the antenna diameter of 0.1 m.						

3.1.6 Estimate the field at the evaluation point

The electric field strength is estimated using the formula below at the investigation point just under the antenna and the edge of the roof.

$$E = \frac{1}{d}\sqrt{30\overline{P}_{\mathrm{avg}} G_i} \quad V/m$$

where

$\overline{P}_{\mathrm{avg}}$ is the average power (W) see 3.1,

G_i is the antenna gain (ratio) relative to the isotropic direction of the evaluation point, and

d is the distance (m) from the source antenna to the evaluation point.

Table 3.1.6 lists the calculated electric field strength for the pre-evaluation. Where the investigation point is just under the antenna mast, the maximum electric field strength is calculated to be approximately 25 V/m at the maximum radio traffic. The pilot channel, which is transmitted at a constant level, is evaluated in the range of 8 V/m to 6 V/m at a distance from 5 m to 15 m. From this pre-evaluation, it can be verified that the field strength on the roof-top does not exceed the ICNIRP reference level.

Table 3.1.6 Calculated electric field strength for pre-evaluation

Investigation point	Electric field		Assumed condition
	Maximum traffic	**Pilot channel**	
Just under antenna mast d=5 [m]	25 [V/m]	8 [V/m]	P_{avg} = 54 W at antenna input connector G_i=10 dBi at out of main beam *Power ratio*=10 between maximum traffic and pilot channel
Edge of roof-top d=15[m]	18 [V/m]	6 [V/m]	P_{avg} = 54 W at antenna input connector G_i =20 dBi at main beam *Power ratio*=10 between maximum traffic and pilot channel

3.1.7 Establish which parameters are to be evaluated

SAR, E or H can be used to evaluate the exposure level because the investigation point on the roof-top is Source-Region II.

3.2. Select evaluation method

In this assessment, the “time and spatially averaged electric field” is selected based on the following considerations as evaluation ranking 3.

- The electric field strength from the RBS has a time variation according to the radio traffic.
- The roof-top is categorized as Environment-Region 1 in which there is a single scatterer.

Furthermore, the “frequency selective measurement” is selected based on the following consideration as Evaluation Method Ranking 1.

- The customer requires exposure assessment based on measurement.
- The roof-top is a complex environment, i.e., the RBS has multiple transmitters and antennas and is categorized as Environment-Region 1. Consequently, calculation of the electric field is more difficult than the measurement.

3.3. Complete the evaluation plan

The following table represents a check sheet for the on-site measurement.

Table 3.3 Checklist for the evaluation

Criteria	Evaluation plan activity	Check
General considerations on safe and practical working on site	Where the evaluation is to be performed on site: • Develop a check sheet to be used on site. • Identify permissions required to work (access) • Consider the safety of the public and people performing the measurements. Ensure that a risk assessment is performed to identify potential hazards and to establish appropriate safety protocols to mitigate them. The procedures and guidance given in IEC 60215 shall be observed where appropriate.	√
Identify parameters relevant to the evaluation	Record all parameters needed for the evaluation and any actions needed to establish/verify their values (see Clause 6 and Annex D). Clearly establish the evaluation configuration and assessment configuration.	√
Evaluation method	Ensure that the selected evaluation method(s) is/are clearly defined together with the reasoning for their selection and clear traceability of their applicability (see Clause 6; Annex D; Annex F; Annex G; Annex I; Annex J; Annex K; Annex N; and, Annex P).	√
Evaluation locations	Define the specific evaluation locations required or give sufficient guidance on how these can be established on site (see Clause 6; Annex A; Annex B; Annex C and Annex K). Ensure that it is clear which evaluation methods are used for each evaluation point.	√
Measurement equipment	Identify measurement equipment to be used, its calibration requirements and compile relevant documentation (Clause 6; Annex E; and, Annex N).	√
Computations	Establish that the computational resources are available (Clause 6 and Annex F). Establish that the appropriate validation work has been completed for the implementation (Clause 6 and Annex H).	√
Uncertainty	For any RF field strength or SAR value reported, define where it lies on the uncertainty probability density function e.g. best estimate, upper 95 %, etc. (See Clause 6; Clause 7; Annex O; and, Annex P). Consider location on source-environment plane (see Annex B) if this affects the uncertainty of the evaluation.	√
Limit evaluations	If comparison with a limit is required: • Define the relevant limit • Define the assessment scheme applicable (Annex M). • Define assessment configuration as well as evaluation configuration (see Clause 3; Annex D; Annex L).	√
Reporting	Establish format for the evaluation report appropriate for the evaluation purpose considering guidance in Clause 8; and, Annex P.	√

3.4. General methodology- field evaluation spatially averaged (see Clauses 6.2.2, 6.4, 6.5 of Standard)

3.4.1 Field measurement selection

The purpose of the evaluation is to demonstrate compliance based on field measurement, when the base station has maximum traffic. The frequency selective method is selected in this case study because signal discrimination is required to measure the pilot channel transmitted from the base station. For maximum exposure, the measured pilot channel is extrapolated using the number of carriers or the power ratio.

3.4.2 Frequency selective measurement method

The electric field measurement equipment is constructed from an isotropic electric field sensor, a frequency selective receiver, and a code selective receiver as shown in Figure 3.4.2.1 overleaf.
The isotropic response of the electric field sensor is obtained by the following calculation with respect to each orthogonal electric field component.

$$E^2 = E_x^2 + E_y^2 + E_z^3,$$

where E is the electric field strength, E_x is the x component of the electric field, E_y is the y component of the electric field, and E_z is the z component of the electric field.

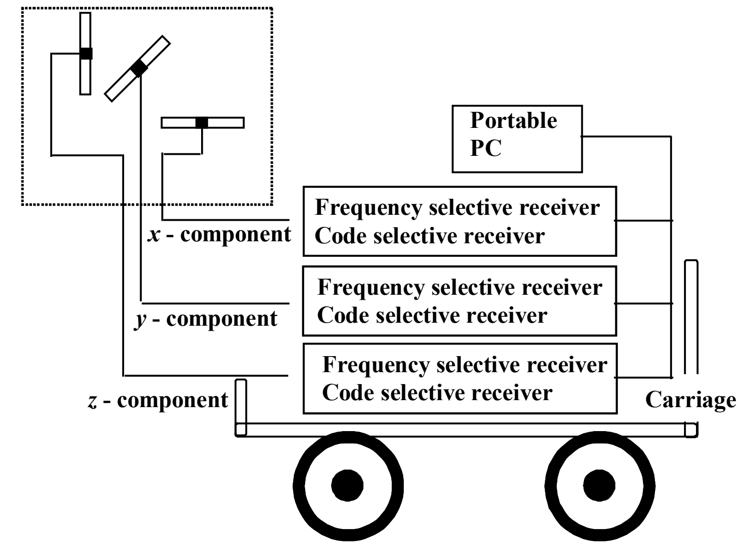


Figure 3.4.2.1 Configuration of electric field measurement equipment

The total exposure ratio, e_{EUT}, regarding the radio base station as the target source is expressed by

$$e_{EUT}^2 = e_{PDC}^2 + e_{UMTS}^2$$

$$e_{PDC}^2 = \sum_{i=1}^{N_{PDC\_Sector}} \sum_{j=1}^{N_{PDC\_Band}} \left(\frac{E_{PDC,i,j}}{E_{R,j}} \right)^2$$

$$e_{UMTS}^2 = \sum_{i=1}^{N_{UMTS\_Sector}} \sum_{j=1}^{N_{UMTS\_Band}} \left(\frac{E_{UMTS,i,j}}{E_{R,j}} \right)^2$$

$$E^2_{PDC,i,j} = (N_{PDC,i,j} + 1) \times E^2_{CCH,i,j}$$

$$E^2_{UMTS,i,j} = \beta_{i,j} \times E^2_{CPICH,i,j}$$

where

- e^2_{PDC} : The total exposure ratio for the PDC system.
- N_{PDC_Sector} : The number of sectors for the PDC system.
- N_{PDC_Band} : The number of frequency bands for PDC system.
- e^2_{UMTS} : The exposure ratio for UMTS.
- N_{UMTS_Sector} : The number of sectors for the UMTS.
- N_{UMTS_Band} : The number of frequency bands for the UMTS.
- $E_{PDC,i,j}$: The electric field strength for PDC with sector-*i* and frequency band-*j*.
- $E_{UMTS,i,j}$: The electric field strength for UMTS with sector-*i* and frequency band-*j*.
- $E_{R,j}$: The reference electric field strength for the exposure limits at frequency band-j.
- $E_{CCH,i,j}$: The electric field strength for the CCH of the PDC system at sector-*i* and frequency band-*j*.
- $N_{PDC,i,j}$: The assigned number of traffic channels at sector-*i* and frequency band-*j*.
- $E_{CPICH,i,j}$: The electric field strength for the CPICH of UMTS at sector-*i* and frequency band-*j*.
- $\beta_{i,j}$: The power ratio for UMTS at sector-*i* and frequency band-*j*.

The total exposure ratio, e^2_{EUT} , is the summation of the exposure from the PDC system and UMTS. The PDC system is simultaneously operated at the frequency bands of 800 MHz and 1.5 GHz. The electric field strength of the control channel, $E_{CCH,i,j}$, is measured by the frequency selective receiver based on the spectrum analyser. The resolution bandwidth of the spectrum analyser is set to the occupational bandwidth, which is approximately 21 kHz. The exposure ratio of the PDC system, e^2_{PDC} , is calculated by the normalization with respect to the reference electric field level at each frequency band. On the other hand, the UMTS is operated in the single frequency band of 2 GHz in this case study. The electric field strength of the common pilot channel, $E_{CPICH,i,j}$, is measured by a code selective receiver, which has a decode function for the code multiplexing signal. The exposure ratio of UMTS, e^2_{UMTS} , is normalized with respect to the reference level at 2 GHz. Table 3.4.2.2 shows each parameter which is required to calculate the total exposure ration from the measured electric field of the pilot channels in this case study.

Table 3.4.2.2 Parameter for Total Exposure from Target Source in this Case Study

Symbol	Value
N_{PDC_Sector}	3
N_{PDC_Band}	2
N_{UMTS_Sector}	3
N_{UMTS_Band}	1
$N_{PDC,i,j}$	$N_{PDC,i,1} =$ 17 $N_{PDC,i,2} =$ 3
$\beta_{i,j}$	$\beta_{i,1} =$ 24

3.4.3 Field measurement technique

The electric field sensor is mounted on a tripod to minimize the influence of the human body. The field strength is measured alone straight across the foot of the antenna mast on the roof-top. The resolution of the measurement grid is 1/2 wavelength at the frequency of 2 GHz to capture the field gradients.

Since the source environment is categorized as Environment-Region 0 or 1 which includes a single scatterer, the spatial averaging in the specific region, which a body occupies, is done to obtain a more accurate exposure level. The electric field strength over the vertical line with the maximum height of 2 m is measured at 50 cm intervals on the straightway, as per the spatial averaging technique. From this spatial averaging, the peak field strength and the average field strength is provided to demonstrate compliance.

The exposure level has time variations because the total transmission RF power from the radio base station depends on the communication traffic. On the other hand, the time variation due to the propagation is not significant because the roof-top is categorized as Environment-Regions 0 or 1 which means that there is no scatter or one reflector exists, respectively. The exposure level at the maximum traffic is evaluated using the extrapolation technique which multiplies the measured field strength of the pilot channels and the number of traffic channels or the power ratio.

4. Results (see Clause 8 of the Standard)

4.1. Results summary- on-site field strength measurement

Figure 4.1 shows the height profile up to 2 m from the surface of the roof-top at the foot of the antenna. Figure 4.2 shows that the total exposure ratio depends on the distance from the foot of the antenna. The maximum and average exposure ratios are 0.026 and 0.01 at the distance of 2 m.

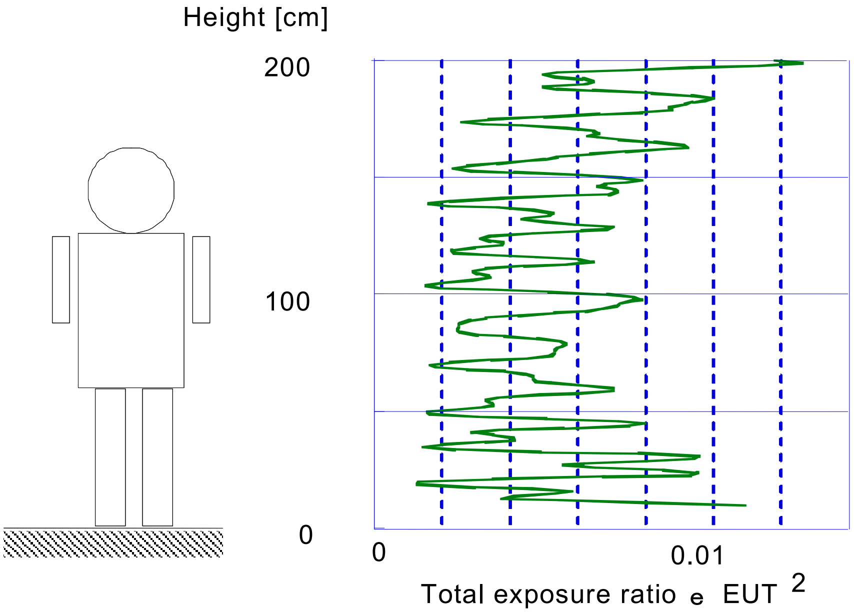


Figure 4.1 Height profile of total exposure ratio at foot of antenna mast

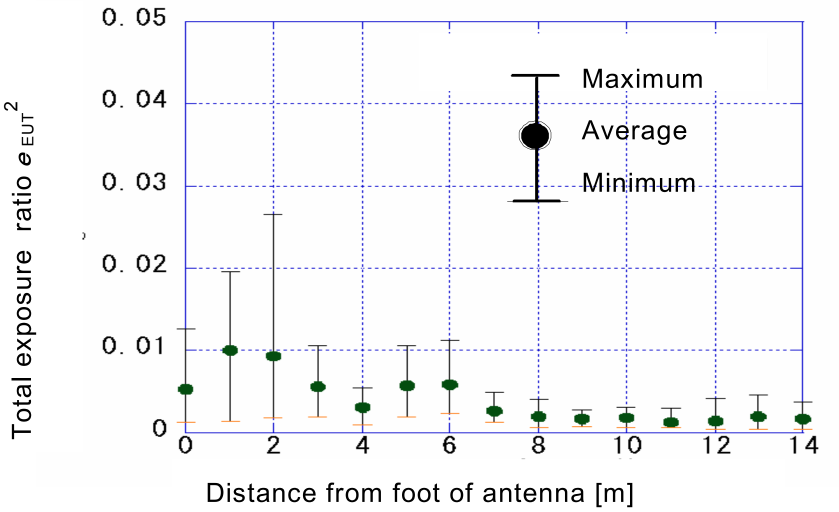


Figure 4.2 Total exposure ratio as a function of distance from foot of antenna

4.2. Assessment scheme – interpretation of results
(see Clause 8 and Annex M of the Standard)

This evaluation was conducted 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.

4.3. Evaluation of compliance within limits

In this case study, the expanded uncertainty is estimated that is less than 3.36 dB, i.e. less than +4dB upper target uncertainty. Therefore, the evaluation comparator values are the 0.026 and 0.01 regarding the maximum and averaged exposure ratio, respectively. The RF field strengths are determined to be below the limit.

5. Conclusions

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.

6. Appendix A (Evaluation Report) - Uncertainty Analysis (see Clause 7 and Annex O of the Standard)

The expanded uncertainty for the field strength measurement is detailed below in Table 6.1.

Table 6.1 Uncertainty calculation for RF field strength measurement

Source of uncertainty (influence quantity)	**unit**	**prob. distrib. type**	**semi span** a	**divisor** d	**sens. coeff.** c	**stand. uncert.** $u = a/d$	c^2u^2
Measurement equipment Total measurement system (meter, cable and probe) uncertainty supplied by manufacturer Including calibration, meter level, antenna factor, antenna factor interpolation, variation due to frequency response of probe/meter, isotropy of the antenna, linearity deviation of the meter / cable/ antenna, cable loss, mismatch, noise and power chain uncertainties)	dB	normal	2.5	2.00	1	1.25	1.563
Methodology Total measurement methodology uncertainty determined to be less than 2 dB	dB	rect	2	1.73	1	1.15	1.333
Source and environment Total uncertainty due to environmental field variations was determined to be less than 0.5 dB	dB	triang	0.5	2.45	1	0.20	0.042
Combined standard uncertainty $u_c = \sqrt{\sum_{i=1}^{N}(c_i^2 u_i^2)}$,							1.71
Coverage factor for 95% CI, k							1.96
Expanded Uncertainty, $U = k X u_c$							3.36

7. Appendix B (Evaluation Report) – Equipment List

7.1. Equipment List

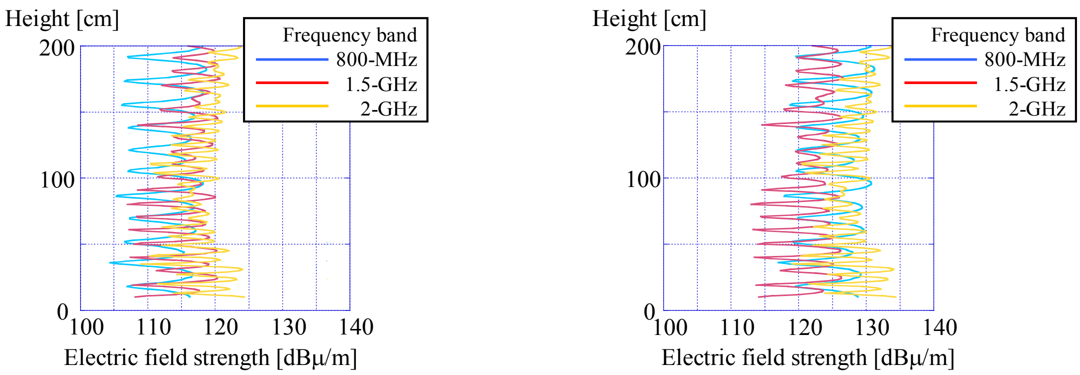
In this evaluation the electric field measurement was performed using the equipment configuration described in Figure 3.4.2.1. This measurement equipment comprised of the field sensor, the receivers and the portable PC as listed in Table 7.

Table 7 Equipment list

Description		Serial number	Calibration due date
Isotropic electric field sensor	KYORITSU CORP. KBA 6701N	0-428-1	20/08/02
Frequency selective receiver	Rohde & SCHWARZ FH-3	100324 100323 100322	14/10/03 14/10/03 14/10/03
Code selective receiver	ANRITSU W-QUEST(32TD)AR	SN6200230241 SN6200247505 SN6200175642	20/01/08 20/01/08 20/01/08
Portable PC	Panasonic Let's Note CF-Y5	6KKSA29311R	

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

The PDC system employs the TD/FDMA technique and uses the 800 MHz band and 1.5GHz band for the transmitting frequency. The frequency selective receiver measures the level of the CCH as the pilot channels from the PDC system. UMTS, on the other hand, employs the W-CDMA radio access scheme using the 2 GHz band for the transmitting frequency. The code selective receiver measures the level of the CPICH. Fig. 8(a) shows the electric field strength from the pilot channels including CCH and CPICH. The electric field strength is extrapolated to estimate the maximum level for the designed available maximum communication traffic of the base station, as shown in Fig. 8(b). From the extrapolated field strength, the total exposure ratios shown in Fig. 4.1 are calculated based on the normalised reference levels for each frequency.



(a) Measured level of pilot channels (b) Extrapolated level from pilot channel

Figure 8. Electric field strength at just under antenna.

Annex F
(informative)

Circular cylindrical compliance boundary determination case study

This annex contains the Circular cylindrical compliance boundary determination case study, referred to in 4.10. 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

Stockholm, Sweden

Björn Hansson
3/9/2009

Evaluation Report Template

Date of Report: 3rd September, 2009	
Title: Compliance boundary generation for a combined LTE and GSM site in Stockholm	
Site Location: Sturegatan 8, 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 Thors	**Date of Evaluation:** 2009-09-01
Identification number of original report: EAB-09:056547 Uen	
Assessor: Björn Thors Senior Research Engineer bjorn.thors@ericsson.com Tel: +46 10 717 18 24	**Quality Assurance:** Martin Siegbahn Senior Research Engineer martin.siegbahn@ericsson.com Tel: +46 10 717 08 11

1. Executive Summary

The purpose of this survey was to determine a radio frequency (RF) exposure compliance boundary (occupational and general public) for a specific combined 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 1.5 m 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

2. Evaluation Overview (see Clause 5 & Annex A of the Standard)

2.1. Site operator information

The test results presented in this report define compliance boundaries for a combined LTE and GSM site in Stockholm where a Kathrein 800 10544 dual band base station antenna is used for transmission in the GSM 1800 and LTE 2600 bands. The maximum operator transmit power was specified at 33 dBm (GSM 1800) and 42 dBm (LTE 2600). Operator technology information is given in Table 1.

Table 1: Operator technology information

Operator	Technology
TeliaSonera	GSM1800, LTE 2600

2.2. Site environment

The base station antenna is mounted on the roof of a building in central Stockholm and oriented to make the antenna main beam point towards a park on the opposite side of the street (see Figure 1).

Figure 1: Photograph showing the base station antenna subject to assessment.

2.3. Exposure safety limits

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

The ICNIRP guidelines contain two sets of basic restrictions, one for occupational exposure and one for the general public. Basic restrictions are given to prevent established adverse health effects related to whole-body heat stress and excessive localized tissue heating. The basic restrictions are given in Table 2.

Table 2: ICNIRP basic restrictions valid in the frequency range 10 MHz – 10 GHz.

Exposure characteristics	Whole-body SAR (W/kg)	Localized SAR in 10g (head and trunk exposure) (W/kg)
General public exposure	0.08	2
Occupational exposure	0.4	10

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

3.1. Pre-evaluation review

3.1.1. Determine evaluation purpose

The evaluation purpose was to establish the compliance boundary in relation to a defined set of limit conditions and to provide SAR information for adult RF exposure.

3.1.2. Determine equipment under test (EUT) category

The equipment under test is defined as a complex RBS.

3.1.3. Determine physical parameters

The physical parameters are given in Table 3.

Table 3: Physical parameters.

Transmission Technology	GSM 1800	LTE 2600
Antenna type number	Kathrein 800 10544	
Horizontal HPBW (deg)	63	58
Vertical HPBW (deg)	7	6.5
Tilt angle (mechanical + electrical) (deg)	4+8	4+7
Directivity (dBi)	17.8	17.5
Number of antenna elements	10	10
Antenna dimensions, height (h) x width (w) x thickness (t)	1389 mm x 323 mm x 71 mm	
Length over which the radiating elements are distributed, L	1350 mm	1130 mm
Smallest radome-antenna element distance in the axial direction (along the height of the antenna), l_a	30 mm	110 mm
Tx frequency band	1805 - 1880 MHz	2620 – 2690 MHz
Transmit power	33 dBm	42 dBm

3.1.4. Decide if ambient fields are to be considered

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

3.1.5. Establish the evaluation locations required

Source regions I and II. Environment region 0.

3.1.6. Establish which parameters are to be evaluated

Localized and whole-body SAR.

3.2. Select evaluation method

The evaluation method chosen for this assessment was SAR estimation.

3.3. General methodology - SAR estimation (see Clause 6.3.2.2 of the Standard)

SAR estimation formulae are given in Annex F.3 of the standard for the front (main beam), back, and axial (above and below) directions. By identifying the variables in the formulae with the physical parameters in Table 2, graphs for localized and whole-body SAR can be generated as function of separation distance for each technology (GSM and LTE) separately. A combined SAR value is then obtained by adding the individual SAR values for each technology (uncorrelated exposure).

3.4. General methodology - compliance boundary construction (see Annex C.3 of the Standard)

The approach adopted here to construct the compliance boundary follows the procedure described in Annex C.3.2.2 of the standard. A circular cylindrical compliance boundary is used as illustrated in Figure 2. The antenna is not located at the center of the cylinder. Instead it is located almost at the edge, facing towards the center of the cylinder. The size of the cylinder is given by the diameter, *D*, and the height, *H*, according to

$$D = D_f + t + D_b$$
$$H = 2(D_a - l_a) + h,$$

where $D_f, D_b,$ and D_a denote the compliance distances in the front, back and axial directions, respectively. The variable l_a denotes the smallest radome-antenna element distance in the axial direction[10] and is introduced since the standard specifies that the distance in the axial direction is measured from the nearest antenna element and not from the radome[11]. The axial compliance distances above and below the antenna are assumed to be equal and the cylinder is anchored a distance D_b behind the antenna. In the equations above t and h denote the antenna thickness and height, respectively.

10 For this antenna this value is equal to 30 mm according to Table 3.

11 For a more conservative assessment, or if the smallest radome-antenna element distance in the axial direction is not available the distance can be taken as the distance from the radome by setting $l_{\mathrm{a}} = 0$.

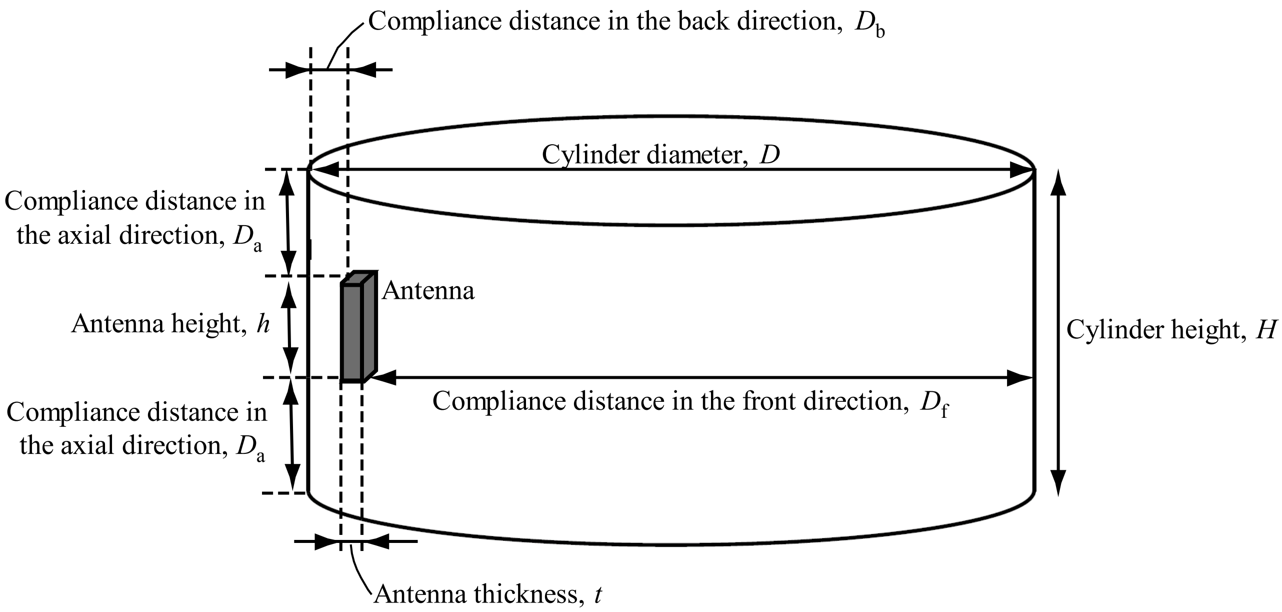


Figure 2: Circular cylindrical compliance boundary[12].

The compliance distances in the front, back and axial directions are calculated by first equating the sum of the SAR estimation formulae for LTE and GSM with the basic restrictions of Table 1 and then solving for the distance. In the main-beam direction, two compliance distances are calculated for localized and whole-body exposure, respectively, and the largest compliance distance is used to calculate the diameter of the cylinder.

12 To keep the figure as simple as possible, the compliance boundary was drawn with $l_a = 0$ mm. In the compliance distance calculations below the true value of $l_a = 30$ mm was used.

4. Results (see Clause 8 of the Standard)

4.1. SAR

Obtained localized and whole-body SAR results are given in Figures 3 and 4 as function of the separation distance. For the front and back directions, the separation distance is measured from the antenna radome. For the axial direction, the separation distance is measured from the nearest antenna element.

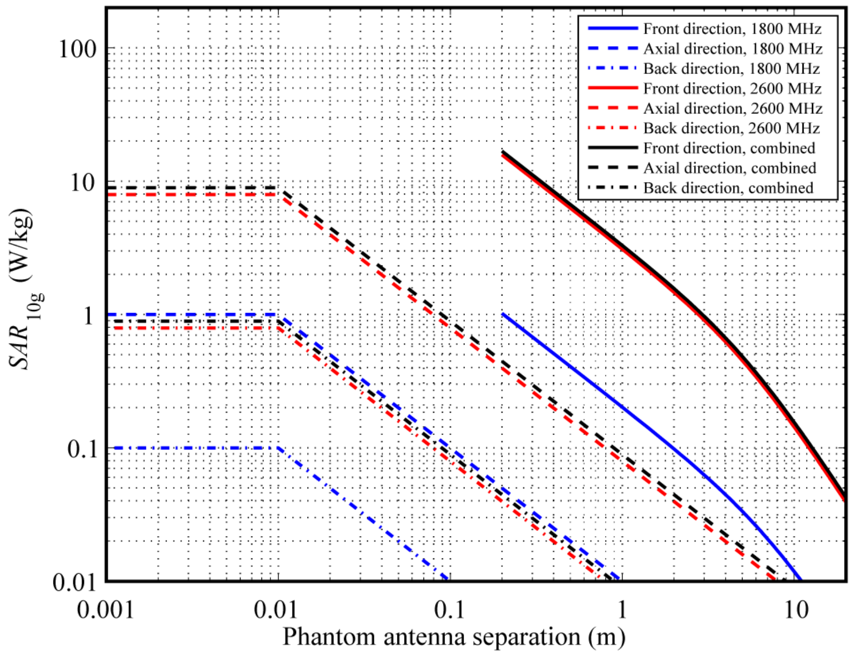


Figure 3: Localized SAR as function of separation distance.

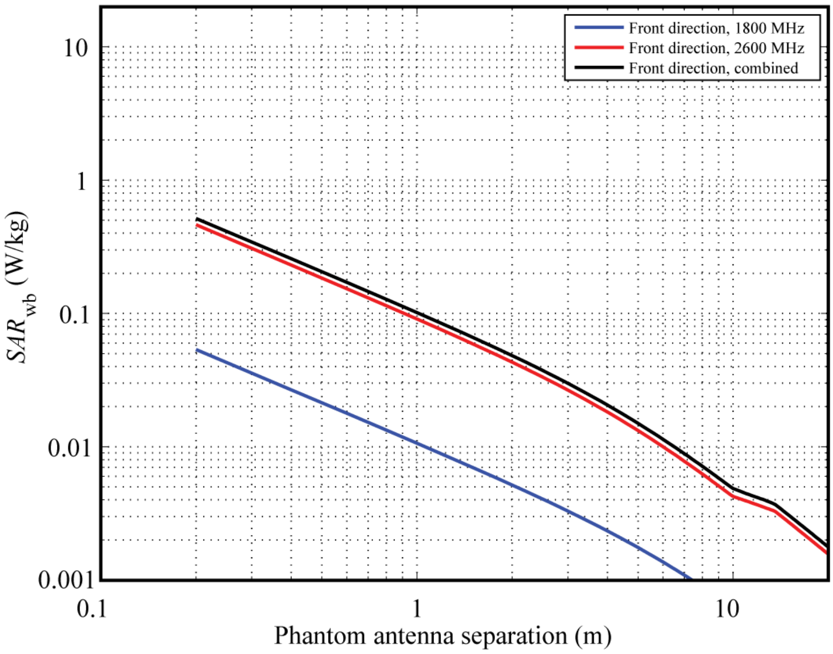


Figure 4: Whole-body SAR as function of separation distance.

4.2. Compliance distance

Following the procedure described above, the height and the diameter of the circular cylindrical compliance boundary were calculated as

$$D^{\mathrm{gp}} = D_f^{\mathrm{gp}} + t + D_b^{\mathrm{gp}} = 1.351\,\mathrm{m} + 0.112\,\mathrm{m} + 0\,\mathrm{m} < 1.5\,\mathrm{m}$$

$$H^{\mathrm{gp}} = 2(D_a^{\mathrm{gp}} - l_a) + h = 2(0.045\,\mathrm{m} - 0.03\,\mathrm{m}) + 1.389\,\mathrm{m} < 1.5\,\mathrm{m}$$

$$D^{\mathrm{occ}} = D_f^{\mathrm{occ}} + t + D_b^{\mathrm{occ}} = 0.276\,\mathrm{m} + 0.112\,\mathrm{m} + 0\,\mathrm{m} < 0.4\,\mathrm{m}$$

$$H^{\mathrm{occ}} = 2(D_a^{\mathrm{occ}} - l_a) + h = 2(0\,\mathrm{m} - 0.03\,\mathrm{m}) + 1.389\,\mathrm{m} < 1.4\,\mathrm{m}.$$

The results are summarized in Table 4.

Table 4: Dimensions of the cylindrical compliance boundaries for the specified configuration (GP=General Public RF exposure, Occ=Occupational RF exposure).

RBS Configurations	Transmitted power (W)	Dimensions of the cylindrical compliance boundary (m)[13]					
		Diameter		Height		Distance behind antenna	
		GP	Occ	GP	Occ	GP	Occ
GSM 1800 + LTE 2600	2 W (GSM) + 16 W (LTE)	1.7	0.5	1.5	1.4	0.0	0.0

13 The calculated compliance boundary dimensions were rounded upwards towards the next decimetre. Note that provided compliance boundary dimensions are valid for adult RF exposure.

A picture of the base station antenna investigated with the calculated compliance boundaries is shown in Figure 5.

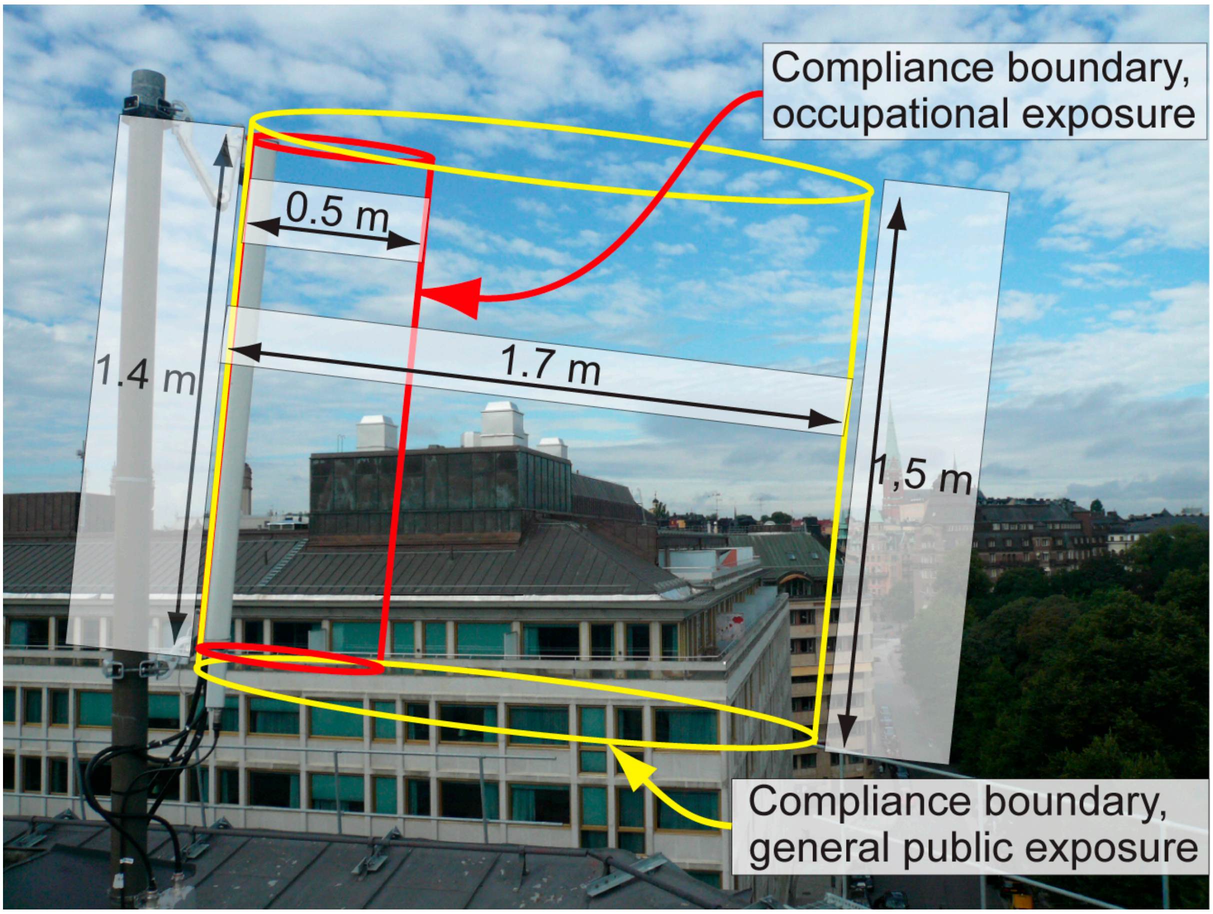


Figure 5: Base station antenna subject to assessment with calculated compliance boundaries (adult RF exposure).

4.3. Assessment scheme – interpretation of results (see Clause 8 and Annex M of the Standard)

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.

4.4. Further information

According to the standard the SAR estimation formulae give a conservative estimate (≥ 95 % confidence level) of localized and whole-body SAR.

5. Conclusions

The compliance boundary for occupational exposure using the cylinder SAR model was assessed to be 0.5m in diameter and 1.4m height in front of the antenna.

The compliance boundary for general public exposure using the cylinder SAR model was assessed to be 1.7m 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.

Annex G
(informative)

Tower case study in parkland

This annex contains the Tower case study in parkland, referred to in 4.7. This evaluation report is presented as issued by Link Microtek and retains its original strcture, formatting, layout and numbering. The standard referred to in the report is IEC 62232

Link Microtek

Evaluation Report

Church Green Essex, United Kingdom.

Hugo Bibby
4/21/2008

Evaluation Report Template

Date of Report: 21st April 2008	
Title: Church Green Essex, Radio Frequency Field Strength Survey Report	
Site Location: Essex, United Kingdom	
Site Coordinates (at Tower base): removed	
***Google Earth* Hyperlink:** removed	
Evaluation laboratory: Link Microtek Ltd. Intec 4.1 Wade Road Basingstoke Hampshire RG24 8NE	**Company/Client:** IEC Standards Evaluation
Evaluation performed by: Hugo Bibby	**Date of Evaluation:** 2008-10-01 only
Identification number of original report: not known	
Assessor: __________________________ Hugo Bibby Director, Link Microtek Ltd	**Quality Assurance:** __________________________ Hugo Bibby Director, Link Microtek Ltd

1. Executive Summary

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 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.

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

2.1. Site operator information

Whilst it was not possible to identify the exact operating frequencies of all the transmitters on site it was possible to identify the mobile operators on the site from the Ofcom sitefinder website. Vodafone and O2 are listed as having macrocell base stations operating at a frequency of approximately 900 MHz with transmitter power levels of 20.72 and 19.1 dBW respectively.

Table 2.1: Operator technology information

Operator	Technology
Vodafone	GSM900, GSM1800, 3G 2100
0_2	GSM900, GSM1800, 3G 2100
Dream FM	Broadcast FM Radio 107.7 MHz
Unknown	Microwave transmission

Notes:

This tower contained numerous microwave transmission dishes that are expected to be operating at low power. Further, there were a number of unknown antennas, which may be connected to operating transmitters, located on the structure.

2.2. Site environment

Figure 2.2 Photograph of tower and immediate surrounds

Adjacent to the tower there is a water reservoir, church, and sporting field. The survey area is gently sloping ground predominately covered with grass. There are some trees, less than 10 m in height, that tend to border property boundaries and the nearby the sporting field. On the day of the evaluation the temperature was approximately 20ºC and the weather conditions dry and sunny.

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. The assessment findings of this report are presented as a percentage of the levels specified in the ICNIRP guidelines.
This assessment compared results against the ICNIRP Guidelines for Time Varying Electric and Magnetic Fields- Reference Levels.
ICNIRP permissible exposure levels vary depending on frequency. The lowest levels occur over the frequency range 10 to 400 MHz. Permissible levels given for microwave frequencies are somewhat higher. ICNIRP guidelines contain two levels, one for occupational exposure the other for the general public. ICNIRP guidelines state that; '*the occupationally exposed population consists of adults who are generally exposed under known conditions and are trained to be aware of potential risk and to take appropriate precautions. By contrast, the general public comprises individuals of all ages and of varying health status, and may include particularly susceptible groups or individuals*'. This can be summarised in Table 2.3 below.

Table 2.3 ICNIRP reference levels for time varying fields

Frequency (MHz)	ICNIRP General Public Level (Wm^{-2})	ICNIRP Occupational Level (Wm^{-2})
10 MHz to 400 MHz	2	10
400 MHz to 2GHz	f/200	f/40
2 GHz to 300 GHz	10	50

For the purposes of this 'broadband' survey the ICNIRP general public reference level was used as the maximum permissible exposure level.

3. Evaluation Plan (see Clause 5.1, 5.2 & Annex A.)

3.1. Pre-evaluation review

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

3.1.1. Determine evaluation purpose

The purpose of the survey was to determine field strength values along footpaths and on a sports field adjacent to a base station site at the Church Green. The maximum values would then be compared against ICNIRP Guidelines.

3.1.2. Determine equipment under test (EUT) category

The Equipment Under Test (EUT) was categorised as a Complex RBS due to the multiple frequency bands and technologies supported.

3.1.3. Determine physical parameters

There were a number of unidentified radio services at the tower which makes the determination of physical parameters challenging. An on-site measurement over the frequency range 100 kHz to 3 GHz was selected as the most appropriate given the variety of VHF and UHF antennas installed on the tower.

3.1.4. Decide if ambient fields are to be considered

Yes. Since the measurement equipment involves a broadband probe there is no filtering of ambient fields that are in the probe bandwidth.

3.1.5. Establish the evaluation locations required

See clause figure 3.4, clause 3.4

3.1.6. Estimate the field at the evaluation point

Experience from previous radio tower surveys like at Church Green shows the radio frequency levels to be very low and well below the ICNIRP limits. Given the limited information on physical parameters, and experience with similar site surveys, an estimate was not conducted.

3.1.7. Establish which parameters are to be evaluated

The maximum field strength levels are to be evaluated and then compared against the ICNIRP guidelines for the general public

3.2. Select evaluation method

The site assessment method chosen for this evaluation was on-site measurement. The clients request for exposure levels along the designated areas and the fact that there were unknown services operating on the tower were contributing factors that influenced the decision to conduct the assessment by measurement.

3.3. Complete the evaluation plan

Develop check sheet to be used on site

3.4. General methodology- field evaluation spatially averaged (see Clauses 6.2.2, 6.4, 6.5 of the Standard)

Radio frequency field strength levels were measured with 'broadband' measurement equipment. This equipment is designed specifically for human safety assessments. It has no frequency selection capability (other than the frequency range of the measurement probe) and has a minimum sensitivity and dynamic range appropriate for comparison with current safety guidelines.

The equipment used during the survey is capable of measuring field strengths down to 0.005% of the ICNIRP occupational reference level. The frequency range of the equipment used was 100 kHz to 3 GHz.

The essential characteristics of the broadband equipment used during this survey are:

1. It is specifically designed for safety assessment.
2. The isotropic probe(s) used receive and evaluate signals from all directions.
3. The probes receive and evaluate signals at all frequencies (within the designated frequency range).

It should be noted that it is possible to measure even lower levels of RF field strength using alternative equipment, i.e. frequency selective equipment such as a spectrum analyser and appropriate antenna. By this means very low field strengths can be measured but the measurement process is more complicated. Equipment of this type was used to provide the plots in Appendix D.

No reference to 'Time Averaging' or 'Spatial Averaging' has been made in this report. These procedures are usually only applied when significant field strengths approaching or exceeding the guidelines are encountered. By employing time or spatial averaging weighting, it is possible to effectively obtain a relaxation of a localised high field (safety guidelines are based on whole body exposure over a period of time – typically six minutes).
The assessment values were recorded along the footpaths and sports field perimeter as shown in red in Figure 3.4 below.

Figure 3.4 – Aerial view of site and survey area

The measurement values were continuously monitored along the footpaths and within the area shown above in Figure 3.4 in red to identify a maximum value. To increase confidence and to provide additional information, values were recorded approximately every 10 m along the footpaths and edges and centre of the sports field.

4. Results (see Clause 8 of the Standard)

4.1. Results summary

The measurement results detailing the maximum survey values for each of the paths and sporting field are summarised in Table 4.1 below.

Table 4.1 Survey Results Summary

Location	Maximum Value % of ICNIRP General Public Reference Level
Path A	0.160
Path B	0.170
Path C	0.295
Sports Field	0.110

The equipment used in the survey comprised a Narda NBM550 meter and Narda probe EF0391 (frequency range 100 kHz to 3 GHz), additional readings were taken using a Narda SRM3001 frequency selective meter.

The results shown in Table 4.1 were obtained from broadband measurements using NBM550 & EF0391 probe. The values were continuously monitored along the footpaths and within the area shown above in red to identify a maximum value. To increase confidence and to provide additional information values were recorded approximately every 10 m along the footpaths and edges and centre of the sports field.

It should be noted that ideally a measurement survey is carried out under worst-case conditions i.e. system(s) operating on full power. The system operating conditions at the time of the survey were unknown so can only be assumed to be normal operating conditions.

Appendix C of this document shows the raw measurement points and values in greater detail.

4.2. Calculation of compliance boundaries

As the compliance limits were not exceeded during the survey the location of the compliance boundaries is unknown.

4.3. Assessment scheme – interpretation of results
(see Clause 8 and Annex M of the Standard)

This evaluation was conducted using the best estimate assessment scheme.

4.4. Further information

Appendix A of this document details the Uncertainty Values, probability distributions and more for each of the sources of uncertainty in this evaluation.

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

Again, the raw measurement data including points and values in greater detail in Appendix C of this report.

While the assessment was predominately conducted with a broadband probe, Appendix D of this report shows plots taken with a frequency selective instrument.

5. Conclusions

All values recorded were well below ICNIRP general public reference levels and as such the compliance limit boundaries were not determined. The maximum values recorded were along path C running from path B to the North-West corner of the sports field. The maximum value recorded corresponds to 0.295% of the ICNIRP reference level.

The ground slopes down quite sharply towards the sports field and it is assumed that the difference in elevation gives rise to the difference in the recorded values over the area of the sports field and those recorded at the higher end of path C.

As the system operating conditions at the time of the survey were unknown it can only be assumed to be normal operating conditions and not worst-case (full power).

To provide further information, plots taken with a frequency selective instrument are included in Appendix D. This instrument is more sensitive than the broadband equipment used for the main survey results and can therefore detect much lower field strength levels. It is important to keep these readings in context and remember that the field strengths represented are tiny percentages of the exposure guidelines. They represent a snap shot in time and the exact contribution from the respective systems may vary over time i.e. one peak seen as higher than others in one plot may be lower at another time.

The plots were taken using a 'maximum hold' setting on the meter so each peak represents a maximum obtained over the period of the measurement. This means that a discrepancy may exist when attempting to compare the values obtained by the broadband measurement method.

From the plots the contribution from the GSM base stations can be seen. The highest peak on the plot is at 107.7 MHz which is a FM radio broadcast frequency. Subsequent investigation revealed that a system transmitting Dream FM at that frequency is installed at the site.

It is worth noting that a number of the signals displayed on the plots are not transmitted by the systems located at the site concerned but have been transmitted from elsewhere.

6. Appendix A (Evaluation Report) - Uncertainty Analysis (see Clause 6; Clause 7 and Annex O of the Standard)

6.1. Uncertainty analysis – on-site field strength

Uncertainty for broadband equipment (NBM550 & EF0391), uncertainty values taken from manufacturer's datasheet can be seen in Table 6.1 below.

Table 6.1 Broadband test equipment uncertainty data

Source of uncertainty (influence quantity)	unit	prob. distrib. type	semi span a	divisor d	sens. coeff. c	corr. factor t	stand. uncert. $u = a/d$	c^2u^2
Measurement equipment								
Total measurement system (meter, cable and probe) uncertainty supplied by manufacturer	dB	normal	3.25	2.00	1	-0.55	1.63	2.641
Combined temperature and humidity response of meter / cable / antenna	dB	rect	0.2	1.73	1	0	0.12	0.013
Methodology								
Probe position in high field gradients Not applicable - test positions not in high field gradients	dB	rect		1.73	1	0	0.00	0.000
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) Not applicable	dB	rect		1.73	1	0	0.00	0.000
Meter reading error of fluctuating signals Not applicable results stored automatically to memory for downloading to pc	dB	triang		2.45	1	0	0.00	0.000
Source and environment								
Spatial Averaging (Not applicable)	dB	rect		1.73	1	0	0.00	0.000
Field reflections from movable large objects near the source during measurement Not applicable - no moving large objects	dB	rect		1.73	1	0	0.00	0.000
RF propagation & environmental clutter loss (for low level environmental measurements) Not applicable	dB	triang		2.45	1	0	0.00	0.000
Combined correction factor, $t_c = \sum_{i=1}^{N} t_i$								-0.55

Combined standard uncertainty, $u_c = \sqrt{\sum_{i=1}^{N}(c_i^2 u_i^2)}$	1.63
Coverage factor for 95% CI, k	1.96
Expanded Uncertainty, $U = k \, X \, u_c$	3.19

Uncertainty for frequency selective equipment (SRM3001/101), uncertainty values taken from manufacturer’s datasheet can be seen in Table 6.2 below.

Table 6.2 Frequency selective test equipment uncertainty data

Source of uncertainty (influence quantity)	unit	prob. distrib. type	semi span a	divisor d	sens. coeff. c	corr. factor t	stand. uncert. $u = a/d$	c^2u^2
Measurement equipment								
Calibration: Manufacturer calibration certificate values used	dB	normal	1.5	2.00	1	0	0.75	0.563
Combined linearity deviation and frequency response of the meter and probe: Manufacturer’s data sheet	dB	rect	1.75	1.73	1	0	1.01	1.021
Isotropy of the antenna: Manufacturer’s data sheet	dB	rect	1	1.73	1	0	0.58	0.333
Combined temperature and humidity response of meter / cable / antenna: Manufacturer’s data sheet	dB	rect	0.2	1.73	1	0	0.12	0.013
Methodology								
Probe position in high field gradients Not applicable - test positions not in high field gradients	dB	rect		1.73	1	0	0.00	0.000
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) Not applicable	dB	rect		1.73	1	0	0.00	0.000
Meter reading error of fluctuating signals Not applicable results stored automatically to memory for downloading to pc	dB	triang		2.45	1	0	0.00	0.000
Source and environment								
Spatial Averaging (Not applicable)	dB	rect		1.73	1	0	0.00	0.000
Field reflections from movable large objects near the source during measurement Not applicable - no moving	dB	rect		1.73	1	0	0.00	0.000

Source of uncertainty (influence quantity)	unit	prob. distrib. type	semi span a	divisor d	sens. coeff. c	corr. factor t	stand. uncert. $u = a/d$	c^2u^2
large objects								
RF propagation & environmental clutter loss (for low level environmental measurements) Not applicable	dB	triang		2.45	1	0	0.00	0.000
Combined correction factor, $t_c = \sum_{i=1}^{N} t_i$								0
Combined standard uncertainty, $u_c = \sqrt{\sum_{i=1}^{N} (c_i^2\ u_i^2)}$								1.39
Coverage factor for 95% CI, k								1.96
Expanded Uncertainty, $U = k\ X\ u_c$								2.72

7. Appendix B (Evaluation Report) – Equipment List

7.1. Equipment list - on-site field strength

Table 7.1. Measurement test equipment details

Measurement equipment				
Monitor	**Type**	**Ser. No.**	**Cal Factor**	**Cal due date.**
Meter	Narda NBM550	A-0083	N/A.	08/03/09
E Field Probe	Narda EF0391	A-0076	As above	08/03/09
Meter SRM 3001/01	Narda SRM	E-0053	N/A	26/07/08
Probe BN 3501/01	Narda SRM probe	E-0026	N/A	26/07/08

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

The results obtained from broadband measurements using NBM550 & EF0391 probe. The values were continuously monitored along the footpaths and sports field to identify a maximum value. To increase confidence and to provide additional information, values were recorded approximately every 10 m along the footpaths and edges and centre of the sports field.

Table 8.1 Measurement survey results

Measurement Location	Value (W/m²)	% of ICNIRP General Public reference level
Path A (starting at southern end)	0.0019	0.095
Path A (running South-North)	0.0022	0.110
Path A (running South-North)	0.0025	0.125
Path A (running South-North)	0.0025	0.125
Path A (running South-North)	0.0028	0.140
Path A (running South-North)	0.0030	0.150
Path A (junction of path A&B)	0.0032	0.160
Path A (running South-North)	0.0023	0.115
Path A (running South-North)	0.0023	0.115
Path A (end of path at northern end)	0.0015	0.075
Path B (starting at western end)	0.0031	0.155
Path B (running East-West)	0.0034	0.170
Path B (running East-West)	0.0023	0.115
Path B (running East-West)	0.0024	0.120
Path B (running East-West)	0.0022	0.110
Path B (running East-West)	0.0020	0.100
Path B (running East-West)	0.0017	0.085
Path B (running East-West)	0.0013	0.065
Path B (running East-West)	0.0013	0.065
Path B (end of path at eastern end)	0.0012	0.060
Path C (higher end)	0.0041	0.205
Path C (higher end)	0.0059	0.295
Path C (sports field level)	0.0017	0.085
Sports field	0.0017	0.085
Sports field	0.0012	0.060
Sports field	0.0007	0.035
Sports field	0.0005	0.025
Sports field	0.0010	0.050
Sports field	0.0010	0.050
Sports field	0.0012	0.060
Sports field	0.0014	0.070
Sports field	0.0013	0.065
Sports field	0.0013	0.065
Sports field	0.0012	0.060
Sports field	0.0011	0.055
Sports field	0.0007	0.035
Sports field	0.0009	0.045
Sports field	0.0009	0.045
Sports field	0.0014	0.070
Sports field	0.0017	0.085

Measurement Location	Value (W/m²)	% of ICNIRP General Public reference level
Sports field	0.0013	0.065
Sports field	0.0011	0.055
Sports field	0.0013	0.065
Sports field	0.0008	0.040
Sports field	0.0011	0.055
Sports field	0.0020	0.100
Sports field	0.0018	0.090
Sports field	0.0022	0.110
Sports field	0.0010	0.050
Sports field	0.0015	0.075
Sports field	0.0013	0.065
Sports field	0.0008	0.040
Sports field	0.0016	0.080

9. Appendix D: Measurement Graphs

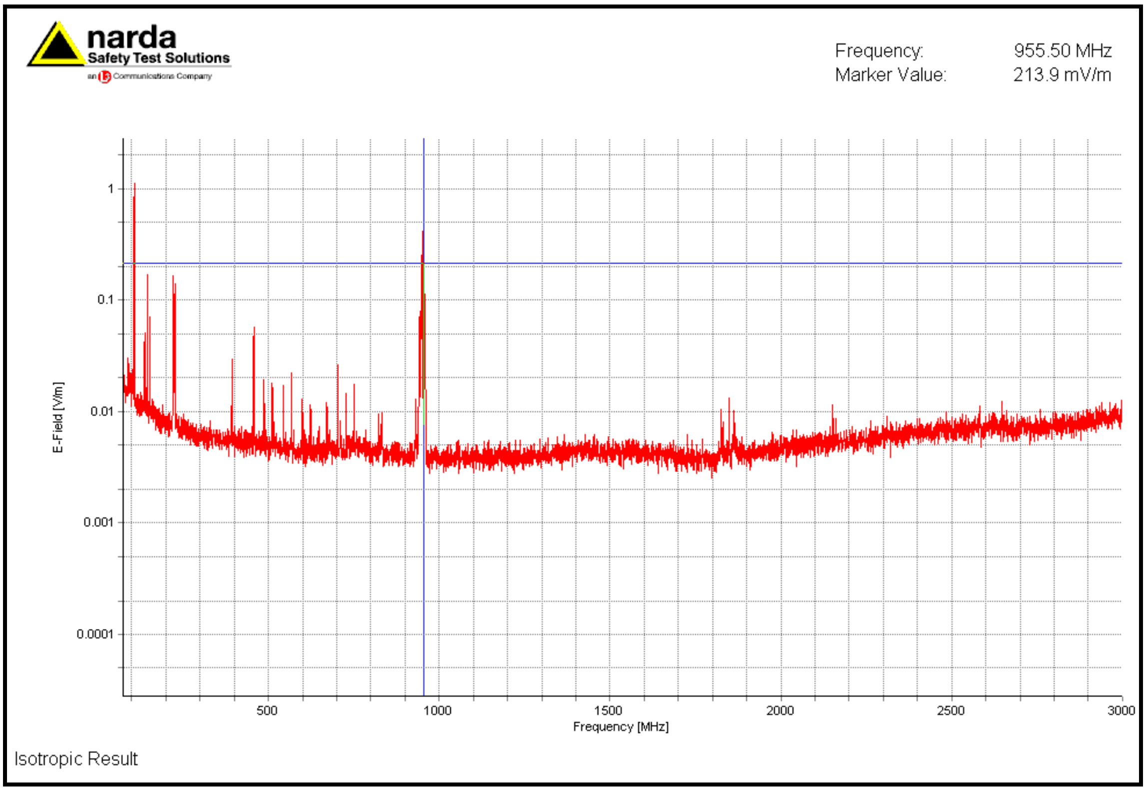


Figure 9.1- SRM-3001 spectrum plot 75 MHz to 3 GHz along 'Path-C.'

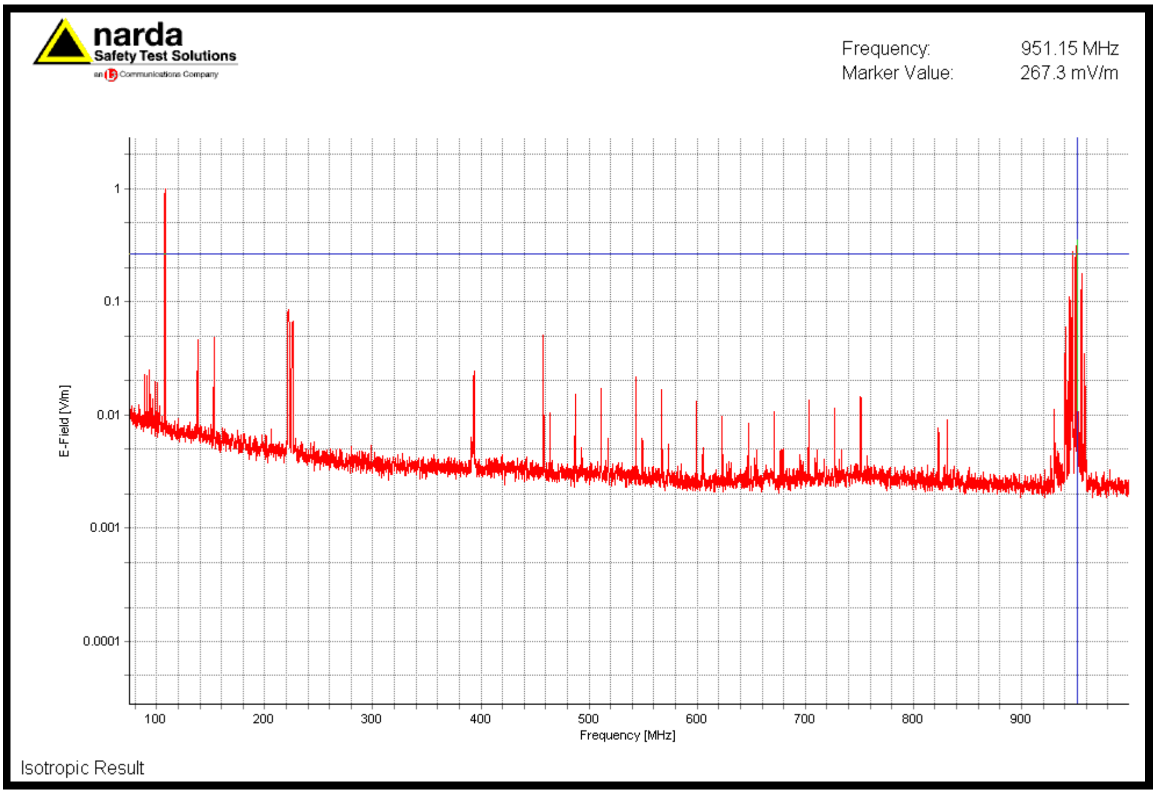


Figure 9.2 - SRM-3001 spectrum plot 75 MHz to 1 GHz along 'Path-C.'

Annex H
(informative)

Tower case study at sports venue

This annex contains the Tower case study in parkland, referred to in 4.8. This evaluation report is presented as issued by Total Radiation Solutions and retains its original structure, formatting, layout and numbering. The standard referred to in the report is IEC 62232.

Total Radiation Solutions

Evaluation Report

Oval in Perth, Western Australia.

Phill Knipe
27/5/2008

Evaluation Report Template

Date of Report: 27th May, 2008	
Title: Perth Oval RF EME Evaluation Report	
Site Location: An oval in Perth, Western Australia	
Site Coordinates (at Antenna): removed	
***Google Earth* Hyperlink:** removed	
Evaluation laboratory: Total Radiation Solutions Suite 1, 315 Railway Road Shenton Park WA 6008 Australia	**Company/Client:** Telstra Corporation Ltd Level 10, 525 Collins Street Melbourne VIC 3000 Australia
Evaluation performed by: Phill Knipe	**Date of Evaluation:** April 2008
Identification number of original report/s: PT62232 Case Study- Evaluation Plan/Modelling/Measurements-PK, PT62232 Pre-Evaluation Review	
Assessor: P. J. Knipe Phill Knipe Consultant Physicist Total Radiation Solutions	**Quality Assurance:** P. J. Knipe Phill Knipe Consultant Physicist Total Radiation Solutions

1. Executive Summary

This case study is the evaluation of RF exposure levels in a sports ground. The purpose of the survey was to determine the maximum field strength contribution from a new cellular base station following its commissioning in order to give reassurance of the low levels where the public have regular access. This base station is one of the several located on lighting towers scattered around the circumference of the sports ground.

The Equipment Under Test (EUT) was categorised as a Complex RBS due to the multiple frequency bands and technologies supported. 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 desktop computation and then verified by on-site frequency selective field strength measurements.

The results were assessed against the Non-Occupational (General Public) reference levels defined in Australian Radiation Protection Standard (based on the ICNIRP Exposure Guidelines 1998).

The modelled maximum cumulative RF EME levels from the RBS were 0.5% of the ARPANSA general public exposure limit.

The measured maximum cumulative RF EME levels from the RBS were 0.04% of the ARPANSA general public exposure limit. The measurement result verifies the conservative outcome of the desktop modelling.

For modelling, a simple Region III (far-field) direct path computation of the field strength at 1.5 m above the ground was performed using a commercially available software package. Using the standard maximum transmit power from the RBS and standard antenna parameters defined by the Australian carriers, this software is designed to provide a conservative estimate of the maximum potential RF field strength. This software was also used to identify the location where the maximum field strength is expected.

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 at frequencies where the power output is known and does not vary with traffic (control channels).

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

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

2.1. Site operator information

The assessment results for this site use measurements to verify the desktop simulation of a macro base station. The network carrier, Telstra, operate three mobile technologies from this facility.

Table 2.1: Operator technology information

Operator	Technology
Telstra	WCDMA850, GSM 900, GSM1800

2.2. Site environment

The site is characterised by a large oval and four separate lighting towers situated along the circumference of the oval. Each of the lighting towers has a separate macro base station operated by a different Carrier/Operator. This evaluation considers only one of the towers, *Structure 1* from figure 1 below. Note, since one of the three sectors of the RBS points directly across the Oval, only the contributions from this sector are considered.

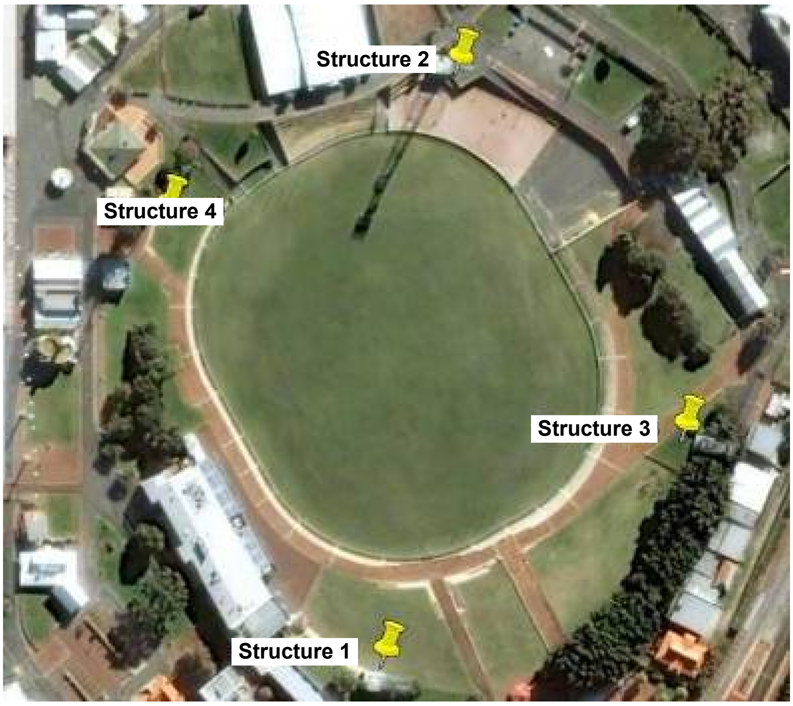


Figure 1 Site photograph - oval antennas on lighting poles

Figure 2 Macro base station on light tower

2.3. Exposure safety limits

The Australian Radio Protection and Nuclear Safety Agency (ARPANSA), an agency of the (Australian) Commonwealth Department of Health has established a Radiation Protection Standard specifying limits for continuous exposure of the general public to RF EME transmissions (Table 2.3). The Australian Standard is based on the ICNIRP Exposure Guidelines.
Further information on the Australian Standard can be gained from the ARPANSA web site at http://www.arpansa.gov.au.

The Australian Communications and Media Authority (ACMA) mandates exposure limits for continuous exposure of the general public to RF EME. Further information can be found at the ACMA website at http://www.acma.gov.au/standards/emr/index.htm .

Table 2.3 Reference levels for time averaged exposure to RMS electric and magnetic fields (unperturbed)

Exposure Category	Frequency Range	E-Field Strength (V/m rms)	H-Field Strength (A/m rms)	Power Flux Density (mW/cm^2)
Occupational (RF Worker)	100 kHz – 1 MHz	614	1.63/*f*	N/A
	1 MHz – 10 MHz	614/*f*	1.63/*f*	$100 / f^{2}$
	10MHz – 400 MHz	61.4	0.163	1
	400 MHz – 2 GHz	$3.07 \times f^{0.5}$	$0.00814 \times f^{0.5}$	$f / 400$
	2 GHz – 300 GHz	137	0.364	5
Non-Occupational (General Public)	100 kHz – 150 kHz	86.8	4.86	N/A
	150 kHz – 1 MHz	86.8	0.729/*f*	N/A
	1 MHz – 10 MHz	$86.8 / f^{0.5}$	0.729/*f*	N/A
	10MHz – 400 MHz	27.4	0.0729	0.2
	400 MHz – 2 GHz	$1.37 \times f^{0.5}$	$0.00364 \times f^{0.5}$	$f / 2000$
	2 GHz – 300 GHz	61.4	0.163	1.0

Notes

1. ***f*** is frequency in MHz
2. 1 mW/cm^2 equals 1,000,000 nW/cm^2
3. There are also applicable limits for exposure to instantaneous RMS electric and magnetic fields (unperturbed fields). These limits are less restrictive than the limits specified in Table 1 and as a result are not referenced in this measurement report.

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

3.1. Pre-evaluation review

3.1.1. Determine evaluation purpose

Determine the RF EME Levels on the oval due to the Telstra Radio Base Station (RBS).

Modelling	Need highest value
Measurements	Need observed value, typical value and highest value

3.1.2. Determine equipment under test (EUT) category

Modelling	Complex RBS
Measurements	Complex RBS

3.1.3. Determine physical parameters

GSM900, 1800 and WCDMA850 technologies present, all parameters are available including specific BCCH frequencies for GSM900 and 1800.

The physical parameters of the site are described in the following tables, and a photograph in Figure 3.

Figure 3 Lighting tower with macro antennas

Table 3.1.3.2 Telstra GSM900 Technology

Sector	1	2	3
Antenna Type	MTPA890-8-ME	MTPA890-8-ME	MTPA890-8-ME
Height (m)	36	36	36
Bearing (° True North)	8	128	210
Tilt (electrical)*	0 – 6 (6)	0 – 6 (6)	0 – 6 (8)
Tilt (mechanical)*	0	0	0
Antennas per sector	2	2	2
Total system loss (dB)*	0	0	0
Power into ports (dBm)*	44	44	44
Measurement height AGL(m)	1.5	1.5	1.5

Table 3.1.3.3 Telstra GSM1800 Technology

Sector	1	2	3
Antenna Type	JTX310DR	JTX310DR	JTX310DR
Height (m)	38	38	38
Bearing (° True North)	8	128	210
Tilt (electrical)	0 - 6	0 - 6	0 - 6
Tilt (mechanical)	0	0	0
Antennas per sector	1	1	1
Total system loss (dB)*	0	0	0
Power into ports (dBm)*	44 44	44 44	44 44
Measurement height AGL(m)	1.5	1.5	1.5

Table 3.1.3.4 Telstra WCDMA850 Technology

Sector	1	2	3
Antenna Type	CPX310R	CPX310R	CPX310R
Height (m)	36	36	36
Bearing (° True North)	8	128	210
Tilt (electrical)*	0 – 6(6)	0 – 6 (6)	0 – 6 (8)
Tilt (mechanical)*	0	0	0
Antennas per sector	1	1	1
Total system loss (dB)*	0	0	0
Power into ports (dBm)*	45 45	45 45	45 45
Measurement height AGL(m)	1.5	1.5	1.5

*Notes:

1. Electrical Antenna Tilt – In Australia the agreed convention for the treatment of electrical tilts is that if the antenna has an electrical tilt of 0-6 degrees then a 0-6 degree pattern envelope will be used. If the electrical tilt is greater than 6 degrees than the actual electrical tilt will be used.
2. Mechanical Antenna Tilt – The actual mechanical antenna tilt will be used.
3. Power into ports – In Australia this is the standard power into each of the ports of the antenna used by the specified technology. The number of antenna ports used for the technology will determine the number of powers listed. This standard power is specified by each of the carriers for each technology used and based upon an agreed configuration. The validity of these standard powers for use was verified by ARPANSA.
4. Total System Loss – The system loss is accounted for in the determination of the standard power into ports values.

3.1.4. Decide if ambient fields are to be considered

Ambient fields not required for inclusion for this test. Ambient fields include other operators located on nearby lighting towers within the oval precinct and the contributions from the Telstra RBS sectors pointing away from the oval.

3.1.5. Establish the evaluation locations required

Modelling	In far field	Region III
Measurements	In far field	

3.1.6. Estimate the field at the evaluation point

Estimate will be completed by modelling software package.

3.2. Select evaluation method

Field E measurement and modelling

3.3. Complete the evaluation plan

Modelling- Simple computation parameters are well known, not much clutter in the environment – open field, direct line of site

Measurement Simple frequency selective measurement with post processing – Maximum hold and spatial with time averaging. Sources present at time of measurement, RBS is operational hence post processing will be required. Data on BCCH channels is known. Have UMTS DEMOD application available.

Safe access to oval and access is readily available

Measurements designed to confirm actual values and check to see if modelled levels are a fair estimate of actual.

3.3.1. General methodology- field evaluation for maximum, time and spatially averaged levels (see Clauses 6.2.2, 6.4, 6.5 of Standard)

The measurements were conducted on 27 May 2008 between 9.00am and 12.00pm. Measurements were performed across the:

1. 935.2 – 943.2 MHz (Telstra GSM900) bandwidth
2. 1805 – 1820 MHz (Telstra GSM1800 WA) bandwidth
3. 880 – 890 MHz (Telstra WCDMA850) bandwidth

Table 3.4 Number of Transceivers per Sector

Technology	Transceivers per Sector
GSM900 Sector 1, 2, 3	4
GSM1800 Sector 1, 2, 3	4
WCDMA850 Sector 1, 2, 3	Single Service Band Present

Measurements to Determine Control Channel RF EME Levels

The measurement location was determined as being the location on the oval, where the modelled maximum occurred. The parameters used for this calculation were based on the standard ones specified in the ARPANSA assessment methodology. These parameters are designed to give a conservative assessment. This location was then located using GPS co-ordinates.

At this location, the area was swept to determine the location of the maximum reading. A height of 1.5 m above ground level was chosen because this is the standard height specified in the ARPANSA assessment methodology. The GSM900 frequency was used because calculations indicated that this would be the highest contributor to the total power density levels due to the RBS.

Once the location of the maximum was found, a series of measurements of the maximum level and the average level of the control channels for each technology at heights of 1.1 m, 1.5 m and 1.7 m were performed. The probe was fixed at each of the heights using a non-conductive wooden tripod.

For the maximum level measurement the meter was set to Max Hold and once the level had stabilised the scan was recorded.

For the average a set number of sweeps (32) were completed and then the resultant scan was recorded.

The recorded measurements taken from the SRM-3000 were frequency - MHz and RF field strength nW/cm2.

4. Results (see Clause 8 of the Standard)

4.1. Results summary- desktop computer modelling

The levels due to the antennas were calculated using the Telstra Research Laboratories (TRL) RF Map software in conjunction with the data gathered from Telstra and antenna manufacturer specification sheets.

The procedures for making the estimates have been developed by the Australian Radiation Protection And Nuclear Safety Agency (ARPANSA). These are documented in the ARPANSA Technical Report; "Radio Frequency EME Exposure Levels - Prediction Methodologies" which is available at http://www.arpansa.gov.au

Table 4.1 – Calculated RF EME levels

Distance from the antennas at origin of Fixed Point Radial in 360° circular bands	Maximum Cumulative EME Level – All carriers at this site (% of ARPANSA exposure limits[2])	Max Cumulative Power Density nW/cm²
0 m to 5 m	0.022%	147
5 m to 50 m	0.14%	588
50 m to 100 m	0.29%	1030
100 m to 200 m	0.28%	1030
200 m to 300 m	0.29%	1040
300 m to 400 m	0.5%	1470
400 m to 500 m	0.21%	1030
Maximum EME level 334.064 m, from the antennas at origin of Fixed Point Radial	0.5%	1470

Table:

1. Estimation for the maximum level of RF EME at 1.5 m above the ground from the existing antennas assuming level ground.
2. The estimated levels have been calculated on the maximum mobile phone call capacity anticipated for this site. This estimation does not include possible radio signal attenuation due to buildings and the general environment.
3. The actual EME levels will generally be significantly less than predicted due to path losses and the base station automatically minimising transmitter power to only serve established phone calls.

For further information see Appendix C- Additional Desktop Modelling Results.

4.2. Measurement Results Summary

Table 4.2.1 Measured Levels of Control Channels (nW/cm^2)

Technology	Measured RF EME Level of Control Channels (nW/cm^2)					
	Maximum			Time Averaged		
	1.1 m	1.5 m	1.7 m	1.1 m	1.5 m	1.7 m
GSM900 (BCCH)	5.112	30.51	31.07	2.722	20.17	19.57
GSM1800 (BCCH)	1.663	1.301	2.31	1.029	0.871	1.485
WCDMA850 (P-CPICH)	4.202	1.963	2.045	3.937	1.776	1.852

Table 4.2.2 Maximum, Time Averaged Maximum, Spatially Averaged Maximum and Time & Spatially Averaged Levels of Control Channels (nW/cm^2)

Technology	RF EME Level of Control Channels (nW/cm^2)			
	Maximum	Time Averaged Maximum	Spatially Averaged Maximum	Time and Spatially Averaged
GSM900 (BCCH)	31.07	20.17	22.23	14.15
GSM1800 (BCCH)	2.31	1.485	1.76	1.13
WCDMA850 (P-CPICH)	4.202	3.937	2.74	2.52

Maximum
Is the maximum RF EME Levels measured for each of the control channels over the three measurement heights.

Time Averaged Maximum
Is the maximum time averaged (number of scans) RF EME Level measured for the control channels over the three heights.

Spatially Averaged Maximum
Is the spatial average of the maximum RF EME Levels measured for each of the control channels over the three measurement heights.

Time and Spatially Averaged
Is the spatial average of the time averaged (number of scans) RF EME Level measured for the control channels over the three heights.

Table 4.2.3 Extrapolation of Measured Control Channel Levels to Determine Possible Maximum Level RF EME Levels (nW/cm^2)

Technology	Extrapolated Possible Maximum RF EME Level (nW/cm^2)			
	Maximum	Time Averaged Maximum	Spatially Averaged Maximum	Time and Spatially Averaged
GSM900 (BCCH)	124.28	80.68	88.92	56.62
GSM1800 (BCCH)	9.24	5.94	7.03	4.51
WCDMA850 (P-CPICH)	52.53	49.21	34.21	31.52
All Technologies	186.05	135.83	130.16	92.65

For GSM900 and 1800 services, the measured level of the control channel (BCCH) represents the total power density due to the BCCH transceiver operating at maximum power. The total possible power density is then calculated by multiplying the measured BCCH power density by the number of transceivers present. Both the GSM900 and 1800 have 4 transceivers per sector.

For WCDMA services the measured level of the control channel (P-CPICH) represents 8 – 12% of the possible total power density due to the transceiver. The total possible power density is then calculated by dividing the measured P-CPICH power density by 8 and then multiplying by 100.

Measurement uncertainty demonstrated in Appendix A

4.3. Assessment scheme – interpretation of results
(see Clause 8 and Annex M of the Standard)

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

The maximum cumulative modelled RF EME level at 1.5 m above ground level is estimated to be 0.5 % of the ARPANSA general public exposure limits (or 1470 nW/cm^2). The expanded uncertainty of the modelling of the maximum RF EME level has been determined to be +3.53 dB and -5.53 dB.

The potential maximum cumulative RF EME level from extrapolating the peak spatial maximum measurement results (first column Table 4.2.3) for the selected measurement location is 0.04% of the ARPANSA general public exposure limits (or 186.05 nW/cm^2). The expanded uncertainty of the measured RF EME level has been determined to be +3.71 dB and -4.61 dB.

The percentage of the standard is determined by comparing the RF EME level against the most restrictive limit applicable for the frequencies currently transmitting from the RBS. This is 0.44 mW/cm^2 (440,000 nW/cm^2) is the general public exposure limit applicable to the minimum transmit frequency of 880 MHz for the WCDMA850 technology.

The measurement outcome verified that the desktop modelling was conservative, producing a result that was 13% of the modelled value, at the assessment location on the oval.

5. Conclusions

The potential maximum cumulative RF EME level from the RBS was evaluated to be below the non-occupational ARPANSA limit using computation and measurements. Considering the uncertainty of the computation and the measurements, the measured and computed values are mutually consistent.

6. Appendix A (Evaluation Report): Uncertainty Analysis Field Strength Measurement (see Clause 6, Clause 7 and Annex O of the Standard)

The expanded uncertainty for the maximum field strength measurement setup is detailed below in Table 6.1

Table 6.1 Expanded Uncertainty (u_c) for field strength measurement.

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 Total measurement system (meter, cable and probe) uncertainty supplied by manufacturer	Including calibration, meter level, antenna factor, antenna factor interpolation, variation due to frequency response of probe/meter, isotropy of the antenna, linearity deviation of the meter / cable/ antenna, cable loss, mismatch, noise and power chain uncertainties)	dB	normal	2.85	2.00	1	-0.45	1.43	2.031
Combined temperature and humidity response of meter / cable / antenna	<1.1 dB for the frequency range 20 MHz to 3 GHz when operating within the temperature range of 15° to 30° C	dB	rect	0.2	1.73	1	0	0.12	0.013
Methodology									
Probe position in high field gradients	Not applicable - test positions not in high field gradients	dB	rect	0	1.73	1	0	0.00	0.000
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

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
Meter reading error of fluctuating signals	No analog meter reading are done – results stored automatically to memory for downloading to pc	dB	triang	0	2.45	1	0	0.00	0.000
Source and environment									
Spatial Averaging	Measured maximum across heights of 1.1, 1.5 and 1.7m	dB	rect	0	1.73	1	0	0.00	0.000
Variation in the power of the RF source from the nominal level	Datasheet of radio manufacturer states Output Power uncertainty to be +- 2 dB	dB	rect	2	1.73	1	0	1.15	1.333
Field reflections from movable large objects near the source during measurement	No moving large objects	dB	rect	0	1.73	1	0	0.00	0.000
RF propagation & environmental clutter loss (for low level environmental measurements)	Low level measurements - low clutter environment	dB	triang	1.5	2.45	1	0	0.61	0.375
Combined correction factor, $t_c = \sum_{i=1}^{N} t_i$									-0.45
Combined standard uncertainty, $u_c = \sqrt{\sum_{i=1}^{N} (c_i^2\ u_i^2)}$									2.12
Coverage factor for 95% CI, k									1.96
Expanded Uncertainty, $U = k \, X \, u_c$									4.16

[1] 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.

[2] The data was obtained from the Narda STS application note “Accounting for measurement uncertainty in the SRM-3000”. A normal probability distribution was assumed.

7. Appendix B (Evaluation Report) – Equipment List

The equipment used in the on-site measurement included:

NARDA SRM-3000 Selective Radiation Meter
Frequency Range 100 kHz – 3 GHz
Serial Number: J-0039

NARDA 3-Axis Antenna
Frequency Range 75 MHz – 3GHz
Model Number 3501/01
Serial Number: H-0009

NARDA RF-cable SRM, Length 1.5m, 50 Ohms
Frequency Range 100 kHz – 3GHz
Model Number 3601/01
Serial Number: E-0046

8. Appendix C (Evaluation Report) – Additional Desktop Modelling Results

Table 8.1 Modelled levels – actual configuration

Distance from the antennas at origin of Fixed Point Radial in 360° circular bands	Maximum Cumulative EME Level – All carriers at this site (% of ARPANSA exposure limits2)	Max Cumulative Power Density nW/cm²
0 m to 5 m	0.022%	147
5 m to 50 m	0.14%	588
50 m to 100 m	0.29%	1030
100 m to 200 m	0.28%	1030
200 m to 300 m	0.29%	1040
300 m to 400 m	0.5%	1470
400 m to 500 m	0.21%	1030
Maximum EME level 334.064 m, from the antennas at origin of Fixed Point Radial	0.5%	1470

The expanded uncertainty for the desktop modelling is detailed below in Table 8.2

Table 8.2 Expanded Uncertainty (u_c) for field strength modelling.

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
System									
Variation in the radiated power of the RF source	Transmitter power can vary.	dB	rect	2	1.73	1	0	1.15	1.33
Cable and system losses	Long cables connect the transmitters to the antennas.	dB	rect	1	1.73	1	-0.5	0.58	0.33
Radiation Loss	Lossy components inside antennas cause radiation loss.	dB	rect	1	1.73	1	-0.5	0.58	0.33
Technique Uncertainties									
Near-field Model Uncertainty	Simplicity of antenna models and the method for determining model parameters limit the accuracy of field predictions.	dB	rect	3	1.73	1	0	1.73	3.00
Environmental Uncertainties									
Reflection and Scattering	Scattering and reflections on top of buildings can create hotspots where E-fields add	dB	rect	1	1.73	1	0	0.58	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^2u^2
	in-phase.								
Combined correction factor, $t_c = \sum_{i=1}^{N} t_i$									-1.00
Combined standard uncertainty, $u_c = \sqrt{\sum_{i=1}^{N} (c_i^2 \ u_i^2)}$									2.31
Coverage factor for 95% CI, k									1.96
Expanded Uncertainty, $U = k \ X \ u_c$									4.53

9. Appendix D: Sample Measurement Scans

This appendix contains sample measurement scans covering the GSM900, GSM1800 and WCDMA850 systems.

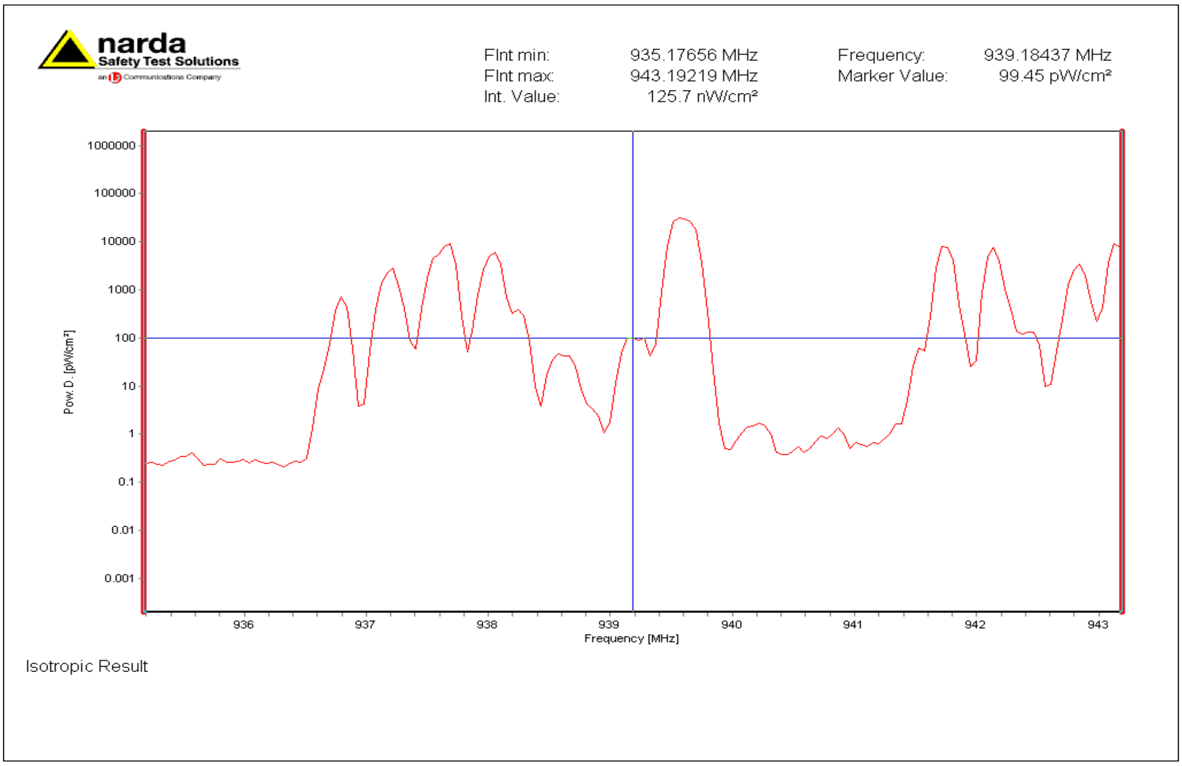


Figure 9.1 Scan 1 – GSM900 – 1.7m

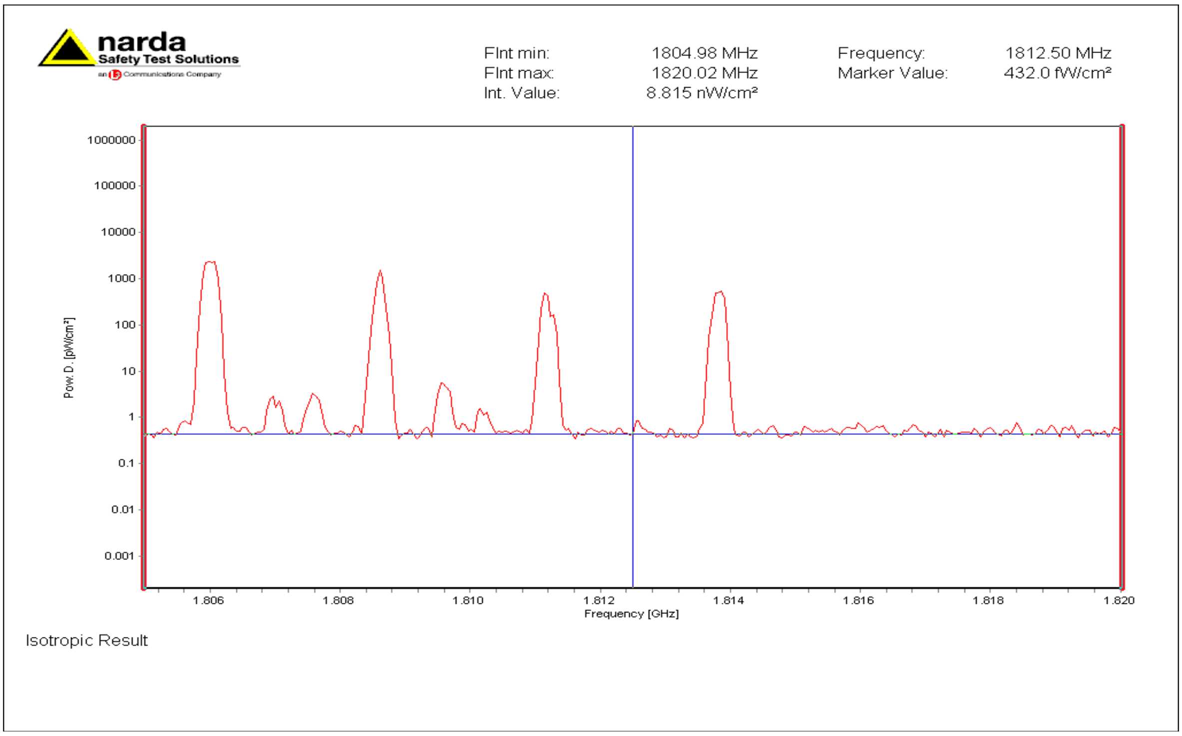


Figure 9.2 Scan 2 – GSM1800 1.7m

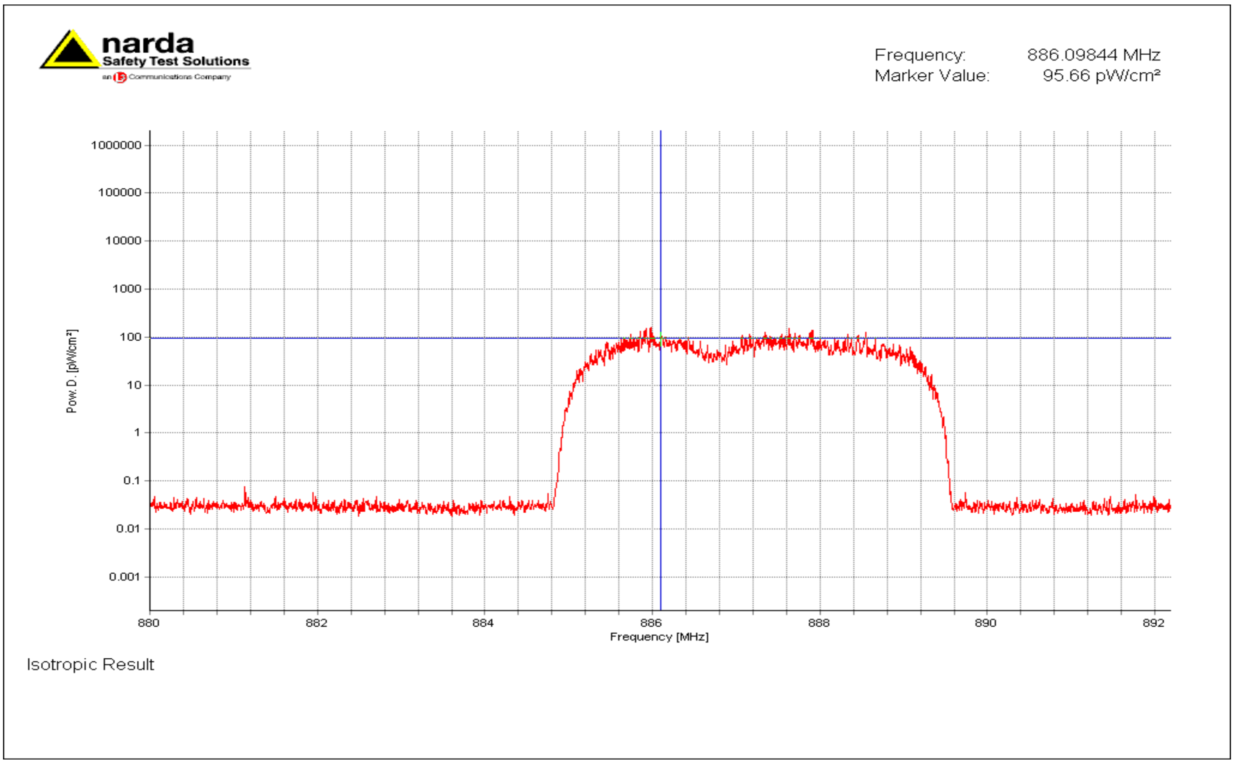


Figure 9.3 Scan 3 – WCDMA850 1.7m

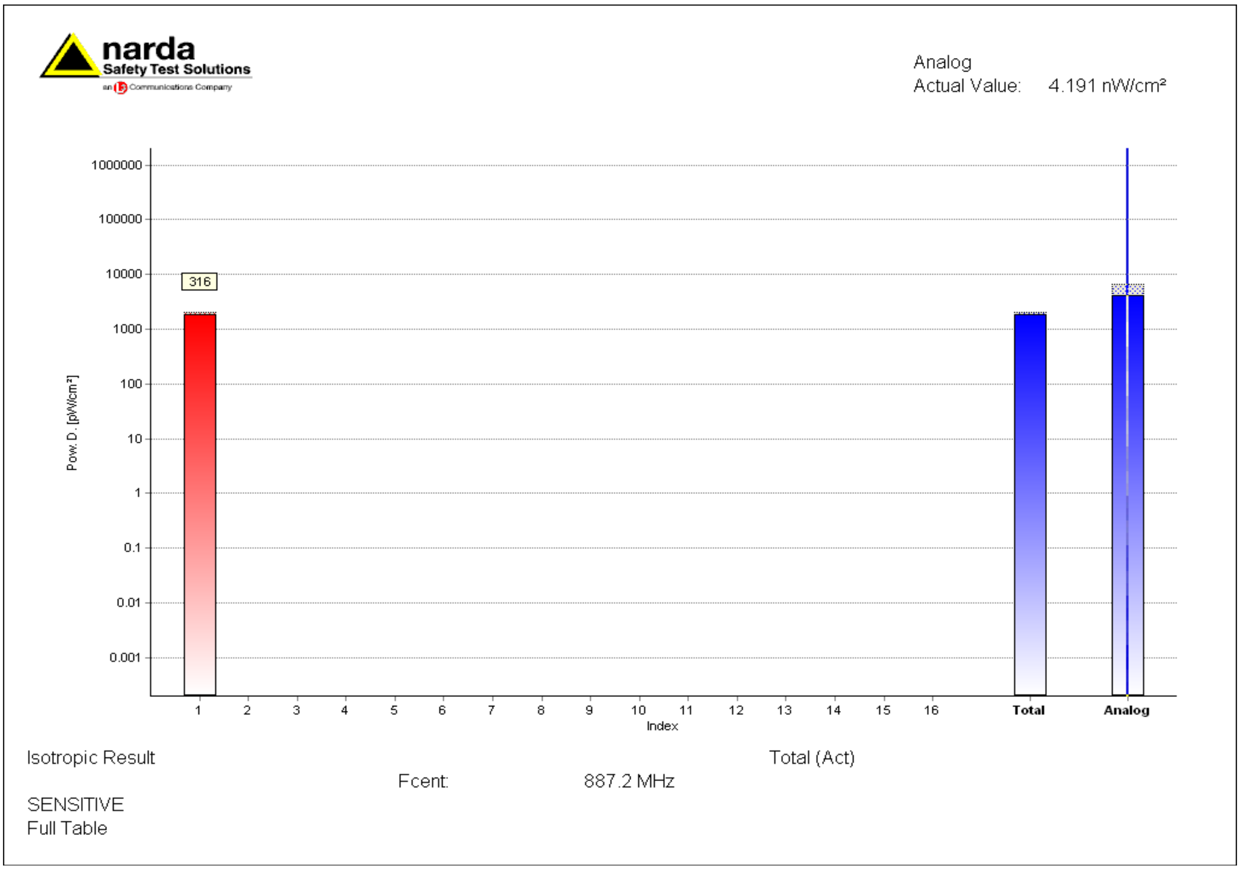


Figure 9.4 Scan 4 – WCDMA850 – DEMOD function

Annex I
(informative)

In-building base station case study

This annex contains the In-building base station case study, referred to in 4.9. This evaluation report is presented as issued by China mobile and retains its original structure, formatting, layout and numbering. The standard referred to in the report is IEC 62232.

China Mobile

Evaluation Report

Beijing, China

TESTING
CNAS L4010

Evaluation Report Template

Date of Report: Aug 2009	
Title: Verification of RF exposure compliance of site with indoor distributed antenna in indoor building coverage (IBC) system	
Site Location: a building in Beijing, China	
Site Coordinates: removed	
***Google Earth* Hyperlink:** removed	
Evaluation laboratory: EMELAB ElectroMagnetic Environment Lab	**Company/Client:** China Mobile
Evaluation performed by: Ma Wenhua Song zhiyuan He Jiwei Hu Yaxi Zhang Dongchen Zhu Wentao	**Date of Evaluation:** Aug 5~10, 2009
Identification number of original report:	
Assessor: Ma Huaxing	**Quality Assurance:** Gao Peng

1 Executive Summary

The purpose of this case study is to verify RF exposure compliance in publically accessible areas for an indoor distributed antenna system. The system comprises a number of antennas mounted on the ceiling of each floor of the occupied office building. The Equipments Under Test (EUT) are the individual radiating antennas on each floor. 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 People's Republic of China (GB 8702-88).

This assessment was conducted using Computational evaluation and on-site Broadband field strength measurement. The final results were based on the field strength measurement.

The maximum RF exposure level measured was 13.83μW/cm^2 with 2.26dB expanded uncertainty on the 14th floor. This is less than the RF exposure reference limits; therefore, the distributed antenna system installed in this building is in compliance with National standard 8702-88 of People's Republic of China (GB 8702-88).

The “best estimate” assessment scheme has been applied for this assessment. The measured levels are reported and the expanded uncertainty is stated.

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

2.1 Site operator information

The computational and measurements results presented in this report defined the RF exposure compliance in an office building, which contained a distributed antenna system for indoor building coverage. This indoor distributed antenna system is mounted on the ceiling of each floor. In most cases, the maximum output power at the antenna port is 15dBm EIRP. In this building, only GSM900 Technology by China Mobile is available.

Table 1: Operator technology information

Operator	Technology
China Mobile	GSM 900

2.2 Site environment

The measurement evaluated five of the IBC antennas. Photographs of the antennas in-situ are shown in Figures 2- 5. Further, a photograph and specific information about the antenna type is listed in Table 2.

Figure 1: Area map with the identified measurement locations

Table 2: Specific information of the chosen indoor antennas

Antenna number	Location	Antenna Dimension [1]/[2]	Height
1	Meeting Hall	12mm/10mm	3.6 m
2	14th floor	12mm/10mm	2.3 m
3	14th floor	12mm/10mm	2.3 m
4	Canteen	12mm/10mm	2.7 m
5	2nd floor	12mm/10mm	2.7 m
Note: The antenna dimensions [1] and [2] are shown in the right.			

Figure 2: Photograph of the indoor antenna in the meeting hall

Figure 3: Photograph of the indoor antenna on the 14th floor

Figure 4: Photograph of the indoor antenna in the canteen

Figure 5: Photograph of the indoor antenna on the 2nd floor

2.3 Exposure safety limits

According to the exposure safety requirements of the National standard 8702-88 of People's Republic of China (GB 8702-88), titled *Regulations for Electromagnetic Radiation Protection*, operators must ensure that their radio communication antenna systems comply at all times with its regulatory limits.

The GB 8702-88 permissible exposure limits vary depending on frequency. The lowest limits occur over the frequency range 30 to 3000 MHz. The standard contains two tiers: limits for RF and microwave exposed workers, and limits for persons not classed as RF and microwaves exposed workers including the general public. The GB8702-88 standard state that; '*exposure to the public is potentially 24 hours a day for 7 days a week, compared with 8 hours a day, 5 days a week for RF and microwave exposed workers*'. The reference limits for the General Public and RF exposed workers are summarized in Tables 3and 4 respectively.

Table 3: GB8702-88 reference limits for the general public

Frequency (MHz)	Electric field intensity (V/m)	Magnetic field intensity (A/m)	Power density (W/m^2)
0.1 to 3	40	0.1	4[1]
3 to 30	$67/\sqrt{f}$	$0.17/\sqrt{f}$	12/f[1]
30 to 3000	12[2]	0.032[2]	0.4
3000 to 15000	$0.22/\sqrt{f}$ [2]	$0.001/\sqrt{f}$ [2]	f/7500
15000 to 30000	27[2]	0.073[2]	2
Note: Averaging time of 6 minutes			

Notes: [1] An equivalent value of plane wave for reference.
[2] Value with rounding approximation and for reference only.

Table 4: GB8702-88 reference limits for the RF exposed workers

Frequency (MHz)	Electric field intensity (V/m)	Magnetic field intensity (A/m)	Power density (W/m^2)
0.1 to 3	87	0.25	20[1]
3 to 30	$150/\sqrt{f}$	$0.40/\sqrt{f}$	60/f[1]
30 to 3000	28[2]	0.075[2]	2
3000 to 15000	$0.5/\sqrt{f}$ [2]	$0.0015/\sqrt{f}$ [2]	f/1500
15000 to 30000	61[2]	0.16[2]	10
Note: Averaging time of 6 minutes			

Notes: [1] An equivalent value of plane wave for reference.
[2] Value with rounding approximation and for reference only.

3 Evaluation Plan (see Clause 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 is to verify RF exposure compliance of the indoor distributed antennas.

3.1.2 Determine equipment under test (EUT) category

The Equipments Under Test (EUT) are each of the individual antennas that together form the complete low power distributed antenna system. There are no other radiating sources at the site under evaluation.

3.1.3 Determine physical parameters

The antenna parameters are given in this section.

Table 5: Physical parameters

Parameters	Indoor distributed antenna
Model	IBC Omni
Frequency range	824-960 MHz
Input impedance	50 Ω
VSWR	<1.5
Gain	3(dBi)
Horizontal HPBW	360°
Vertical HPBW	824 MHz~960 MHz 60°~110° 1710 MHz~2500 MHz 30°~65°
Directivity	Omni directional
Maximum power	50 W into system 15 dBm into any individual antenna
Polarization	Vertical
Dimensions	Φ120 mm×100 mm
Weight	410 g

3.1.4 Decide if ambient fields are to be considered

The indoor distributed antenna is mounted on the ceiling. There are no other sources of RF fields in line-of-sight. In this case, ambient fields need not be evaluated.

3.1.5 Estimate the field at the evaluation point

Computational evaluation of the site was performed to estimate the RF field strength before actual measurement. The result of the computational evaluation estimates the RF field strength at the evaluation site.

3.1.6 Establish which parameters are to be evaluated

The power density value (S) is determined for each measurement locations, and the expanded uncertainty of measurement is analyzed too.

3.2 Select evaluation method

Computational evaluation and on-site Broadband field measurement are 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 computation and on-site measurement, respectively.

Table 6: Computational evaluation check-list

Step	Description
1	Use the formula in Annex F2.3
2	Specify power at the antenna port and antenna gain
3	Specify the distance *d* from the measurement location to the antenna
4	Calculate S corresponding to different *d*
5	Analyze results

Table 7: On-site measurement check-list

Step	Description
1	On each location, ensure the probe occupy the expected position
2	Then, take measurements for a total of 30 seconds.
3	Record the strongest field level of the temporal variations of the signals.
4	Repeat step 2&3 for 10 times.
5	Repeat steps 1 to 4, for every unique location.

3.4 Methodology of on-site measurement

Where on-site measurement is required to verify RF exposure compliance, the following steps should be taken into account:

1. In the indoor environment, the RF field of antenna close to the antenna suffers few disturbances compared with outdoor antennas. Therefore an environment search does not need to be performed.
2. Ensure that the measurement is performed during the normal working time of the IBC. 8:00~20:00 is the proposed measurement time.
3. Broadband equipment is prepared for on-site measurements.
4. Computational evaluation should be made to estimate RF levels for the surveyed antenna as a way to identify approximately the locations to be measured.
5. Normally the locations are in the far field of every radiating element, so the E-field (Power Density) probe is sufficient.
6. A written record should be kept of the measurement locations, distance and reading levels.
7. Measurement uncertainties must be taken into account during the survey.
8. Normally the probe is mounted on a non-metallic tripod at a height of 1.8m. Occasionally, the evaluation may require the probe to be held by the surveyor. Under such conditions, the probe should be held away from the surveyor and pointed towards the antenna being evaluated. Further, the surveyor should be standing away from other objects and neither directly in front nor behind the probe relative to the antenna position.
9. Normally the measurement locations are chosen horizontally, and start from the

projection of the antenna on the plane which is parallel to the ground at a height of 1.8m. These are shown as measurement points A-F in Figure 3.4. With the possibility of maintenance personnel working in proximity to the ceiling,(for example dome light maintenance), another group of measurement locations was required. These measurement points, labelled as points G-K in Figure 3.4 below, were positioned parallel to the ground 30cm from the ceiling. Further details can be found in Appendix B.

10. Normally, a scan of approximately 30 seconds should be considered sufficient, provided the probe has a fast enough response time.

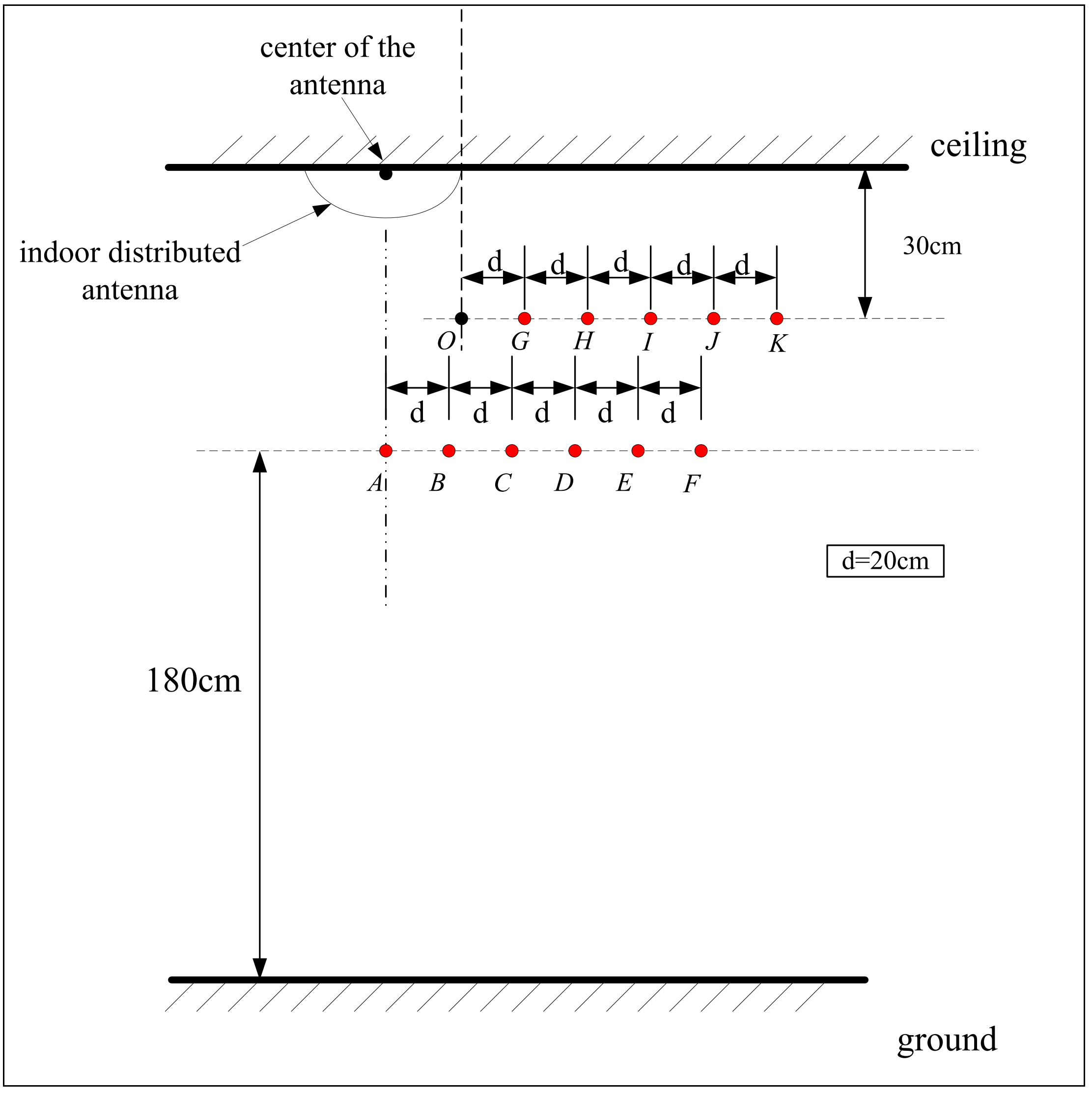


Figure 3.4 Testing points for on-site measurement

4 Results (see Clause 8 of the Standard)

4.1 Results summary-computational evaluation

The RF exposure levels due to each antenna have been calculated. The computational evaluation was performed using the data provided in Table 8. The results of the computational evaluation concluded that the estimated Power Density (μW/cm^2) was considerably less than the limits of GB8702-88 for general public exposure.

Table 8: Input parameters list

Power at antenna port (dBm)	Antenna gain (dBi)	Measurement location(from the antenna) (cm)
15	3	20
15	3	40
15	3	60
13	3	20
13	3	40
13	3	60
10	3	20
10	3	40
10	3	60

Table 9: Computational results list (μW/cm$^{2)}$

Antenna power (dBm) / Measurement location	15	13	10
20	12.55	7.92	3.97
40	3.14	1.98	0.99
60	1.40	0.88	0.44
80	0.78	0.50	0.25
100	0.50	0.32	0.16
120	0.35	0.22	0.11
140	0.26	0.16	0.08
160	0.20	0.12	0.06

4.2 Results summary – on-site measurement

Considering the distributed antennas are mounted on the ceiling and that the closest point of human access would be the head, spatial averaging is not required. Each location is tested 10 times for 30 seconds per time with the peak level recorded.

Six measurement points are chosen for each indoor antenna as described in Appendix B.

This RF evaluation measurement is carried out on the 2nd, 14th, 15th floor respectively with Narda NBM-550. Tables 10-14 represent the measurement value of 11 points for each antenna. The uncertainty assessment is presented in appendix A.

4.2.1 Antenna 1

Location: 15th floor; Antenna Height: 3.6m

Table 10 Results for antenna 1

Test points	Average, μW/cm² (10 readings)
A	0.20
B	<0.10
C	0.10
D	0.20
E	0.30
F	0.20
G	4.36
H	6.45
I	1.59
J	2.36
K	0.48

4.2.2 Antenna 2

Location: 14th floor; Antenna height: 2.3m

Table 11 Results for antenna 2

Test points	Average, μW/cm² (10 readings)
A	0.60
B	1.35
C	2.92
D	2.63
E	2.02
F	2.24
G	7.10
H	13.83
I	2.56
J	6.83
K	6.61

4.2.3 Antenna 3

Location: 14th floor; Antenna height: 2.3m

Table 12 Results for antenna 3

Test points	Average, μW/cm^2 (10 readings)
A	0.53
B	0.48
C	1.75
D	3.62
E	0.90
F	1.49
G	5.38
H	8.12
I	8.60
J	7.50
K	3.74

4.2.4 Antenna 4

Location: 2nd floor; Antenna height: 2.7m

Table 13 Results for antenna 4

Test points	Average, μW/cm^2 (10 readings)
A	0.23
B	0.47
C	0.55
D	0.83
E	0.63
F	0.37
G	5.79
H	8.15
I	2.16
J	2.71
K	0.52

4.2.5 Antenna 5

Location: 2nd floor; Antenna height: 2.7m

Table 14 Results for antenna 5

Test points	Average, $\mu W/cm^2$ (10 readings)
A	0.17
B	0.40
C	0.39
D	0.20
E	0.18
F	0.10
G	0.12
H	0.13
I	0.10
J	<0.10
K	0.10

As the previous tables illustrate, the RF field strength levels from the on-site measurements are less than the limits for the public exposure as defined in GB8702-88. As such these evaluation locations were deemed safe to the general public. The results indicate that the exposure levels are inversely proportional to the height of the antennas; a fact confirmed by the maximum measured values on the 14th floor where the ceiling height is the lowest.

4.3 Assessment scheme – interpretation of results (see Clause 8 and Annex M of the Standard)

The “best estimate” assessment scheme has been applied for this assessment. The measured levels are reported and the expanded uncertainty is stated.

5 Conclusions

The maximum value measured by the surveyors is 13.83μW/cm^2 with 2.26dB expanded uncertainty. Even at this location, which was on the 14th floor, the RF field strength was significantly less than the general public limits of GB8702-88. With the measurement position being 2.0m from the floor, and the space above the measurement location inaccessible to the general public, this building was found to be in compliance with the National standard 8702-88 of People's Republic of China (GB 8702-88).

6 Appendix A - Uncertainty Analysis

The expanded uncertainty for the maximum field strength measurement setup is detailed below in Table 6.1

Table 6.1 Expanded Uncertainty (u_c) for field strength measurement NBM550 with EF0391.

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 Calibration	Manufacturer calibration certificate values used	dB	normal	1.5	2.00	1	0	0.75	0.563
Linearity deviation of the meter and probe	Manufacturer's data sheet	dB	rect	0.5	1.73	1	0	0.29	0.083
Frequency response of the meter and probe	Manufacturer's data sheet	dB	rect	1	1.73	1	0	0.58	0.333
Isotropy of the antenna	Manufacturer's data sheet	dB	rect	1	1.73	1	0	0.58	0.333
Combined temperature and humidity response of meter / cable / antenna	Manufacturer's data sheet	dB	rect	0.2	1.73	1	0	0.12	0.013
Methodology									
Probe position in high field gradients	Not applicable - test positions not in high field gradients	dB	rect		1.73	1	0	0.00	0.000
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		1.73	1	0	0.00	0.000
Meter reading error of fluctuating signals	No analog meter reading are done – results stored automatically to memory for downloading to pc	dB	triang		2.45	1	0	0.00	0.000
Source and environment									
Spatial Averaging		dB	rect		1.73	1	0	0.00	0.000

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
Variation in the power of the RF source from the nominal level	Datasheet of radio manufacturer states Output Power uncertainty to be +- 2 dB	dB	rect		1.73	1	0	0.00	0.000
Field reflections from movable large objects near the source during measurement	No moving large objects	dB	rect		1.73	1	0	0.00	0.000
RF propagation & environmental clutter loss (for low level environmental measurements)	[Not applicable - high level environment in direct line of sight to source?]	dB	triang		2.45	1	0	0.00	0.000
Combined correction factor, $t_c = \sum_{i=1}^{N} t_i$									0.00
Combined standard uncertainty, $u_c = \sqrt{\sum_{i=1}^{N} (c_i^2\ u_i^2)}$									1.15
Coverage factor for 95% CI, *k*									1.96
Expanded Uncertainty, $U = k\ X\ u_c$									2.26

7 Appendix B- On-site measurement

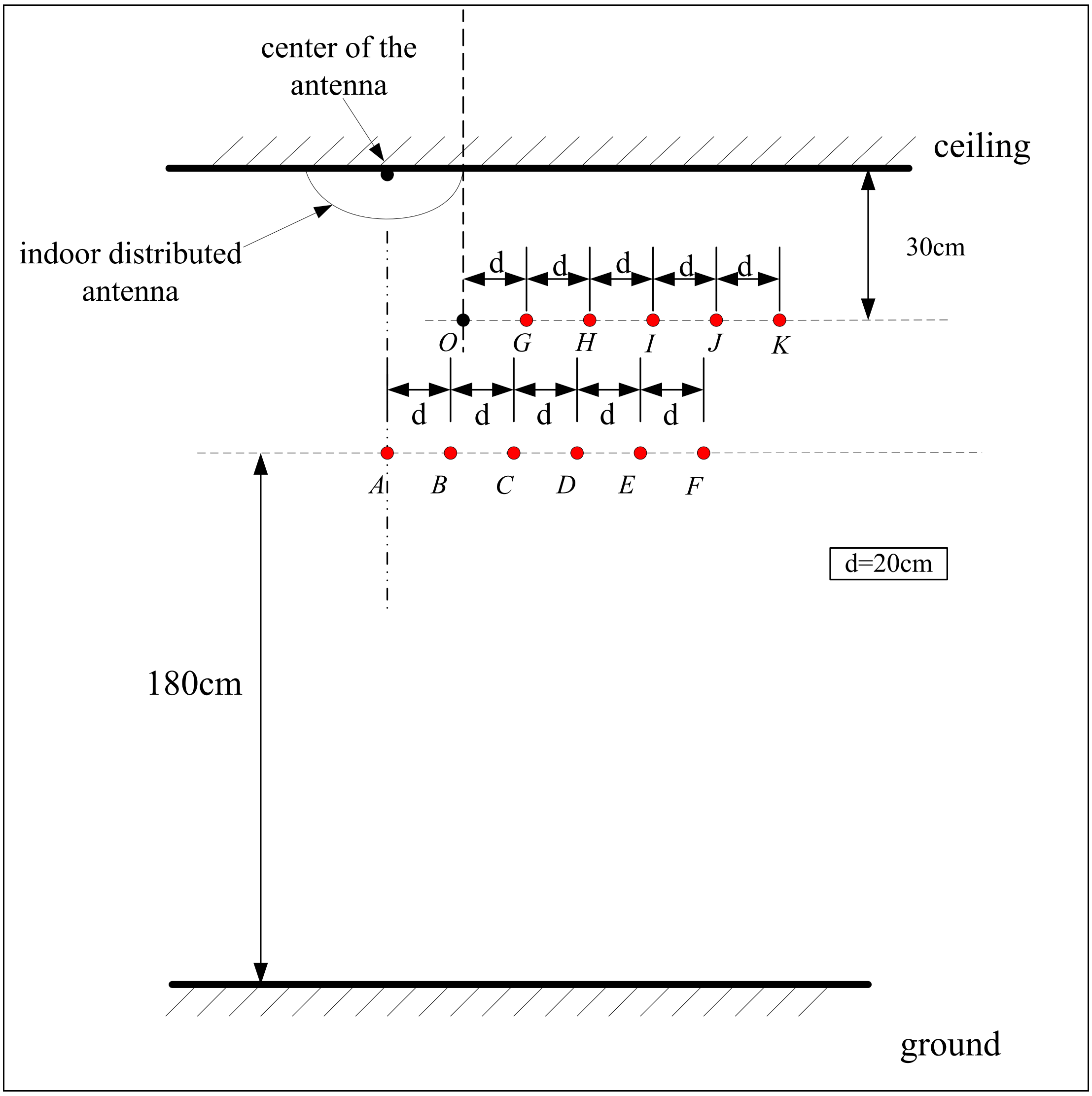


Figure B.1 Testing points for on-site measurement

When on-site measurements are required to verify RF exposure compliance, the following steps should to be taken into account:

1. Prior to on-site measurement, the surveyor should walk around under the indoor ceiling-mounted antenna using the Narda SRM-550 to find the maximum RF exposure orientation (assuming the antenna is the centre of the area evaluated);
2. Figure B.1shows the eleven distributed measurement points which were selected at each measurement location. The distributed measurement points, labelled A-F, spaced 20cm apart were 1.8m above the ground/floor with Point A being just below the centre of the evaluated antenna. Additional measurement points G-K, were located 30cm from the ceiling and parallel to the ground. Point G being 20cm away from point O, which is below the edge of the indoor distributed antenna (noting that O is not test point).
3. Each point was tested 10 times, with a measurement period of 30 seconds.
4. According to the result of the on-site measurements, the location where RF exposure is the strongest will be identified.

Table B.1 Template of test data records

Test points	□E（V/m） □PD（μW/cm²）										average
	Measured values										
	1	2	3	4	5	6	7	8	9	10	
A											
B											
C											
D											
E											
F											

8 Appendix C- Equipment List

NARDA Broadband Meter (NBM-550) with tri-axial probe and a tripod. The last calibration was performed on Oct 17, 2008.

9 Appendix D- Uncertainty Analysis Tools

The evaluation was conducted using a self-developed uncertainty analysis tool — Uncertainty Calculation Software. A screenshot of the software is shown in Figure D.1.

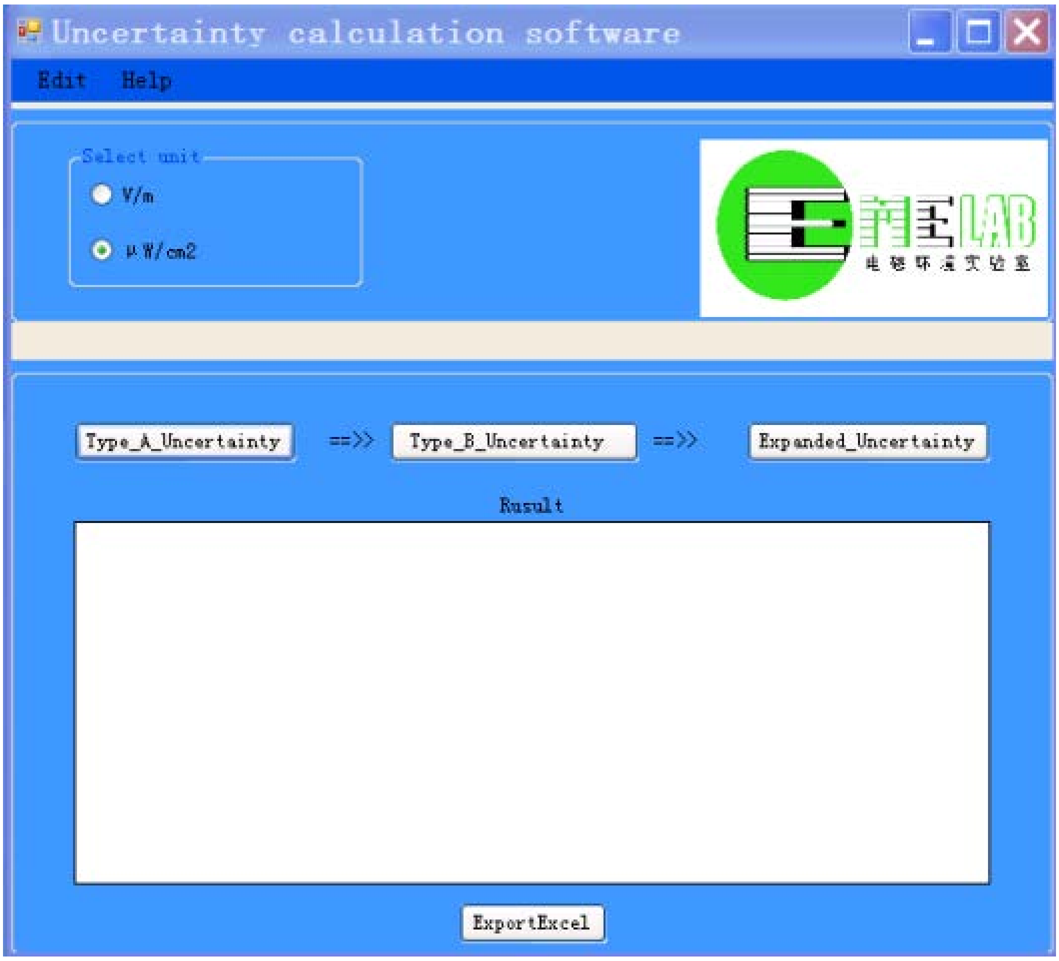


Figure D.1 Uncertainty calculation software

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END OF CASE STUDIES

Annex J
(informative)

Evaluation template and sample uncertainty table

J.1 Evaluation template

Below is an embedded document template which may be used for evaluations. It is based on the format for the case studies presented within this document and is provided in the Microsoft Word (97-2003) doc format.

Evaluation
template.doc

J.2 Sample uncertainty table

Below is an embedded document table spreadsheet to assist with measurement uncertainty. It is based on the uncertainty Tables of the Standard and may be of assistance for evaluations. It is provided in the Microsoft Excel (97-2003) format.

IEC62232
Uncertainty Tables.xl

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