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TECHNICAL REPORT

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

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

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

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

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

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

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

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

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- withdrawn,
- replaced by a revised edition, or
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INTRODUCTION

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

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

1 Scope

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

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

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

2 Normative references

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

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

3 Terms, definitions, symbols and abbreviated terms

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

4 Overview of case studies

4.1 Case study synopsis

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

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

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

4.2 Micro cell case study

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

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

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

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

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

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

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

This case study illustrates:

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

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

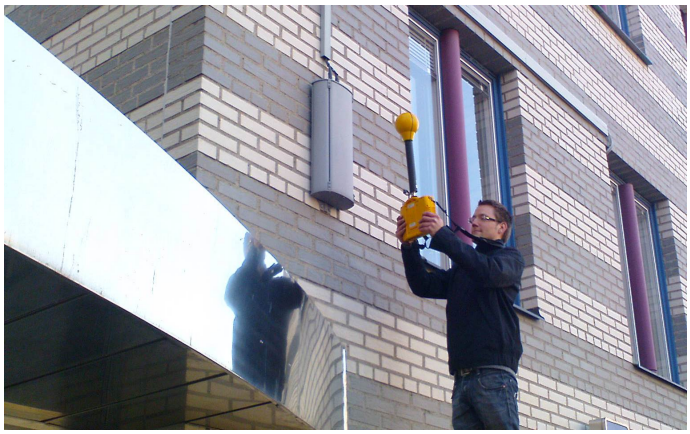

Figure 1 – Micro cell case study

4.3 Roof-top case study with nearby apartment buildings

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

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

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

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

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

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

This case study illustrates:

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

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

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

4.4 Roof-top / tower case study in residential area

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

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

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

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

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

This case study illustrates:

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

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

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

4.5 Roof-top case study with direct access to antennas

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

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

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

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

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

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

This case study illustrates:

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

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

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

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

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

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

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

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

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

This case study illustrates:

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

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

The case study is available in full in Annex E.

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

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

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

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

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

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

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

This case study illustrates:

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

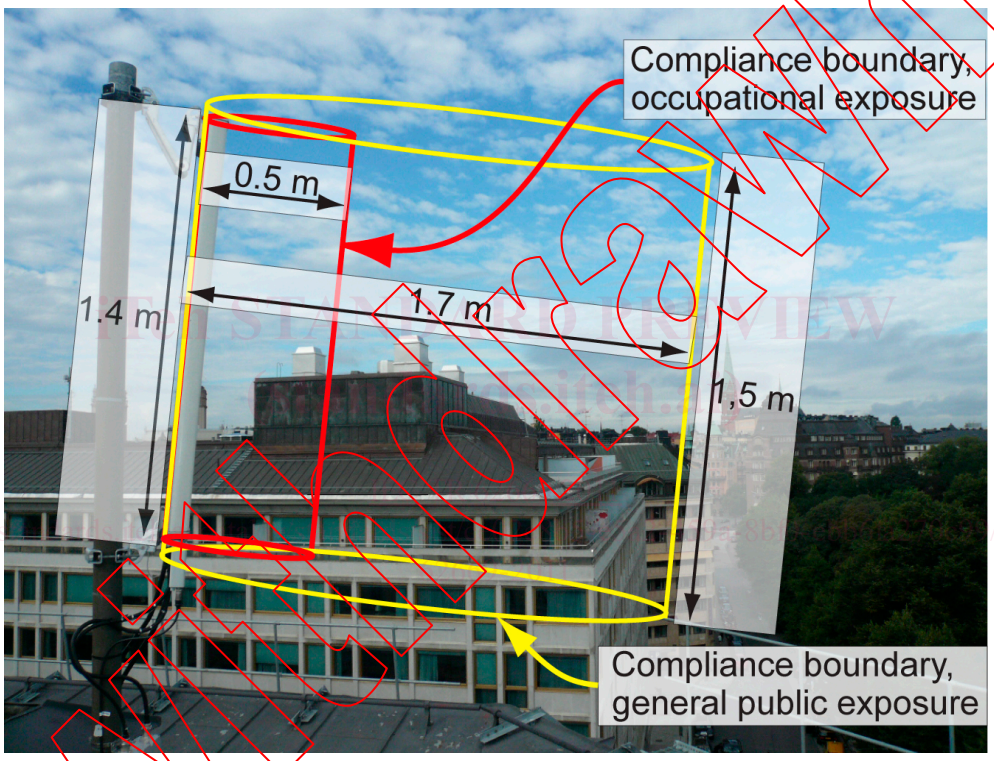

Figure 6 – Cylindrical compliance boundary determination for dual band antenna on building

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

The case study is available in full in Annex F.

4.8 Tower case study in parkland

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

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

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

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

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

This case study illustrates:

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

Figure 7 – Tower case study in parkland

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

The case study is available in full in Annex G.

4.9 Multiple towers case study at sports venue

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

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