



BSI Standards Publication

**Determination of RF field strength, power density
and SAR in the vicinity of radiocommunication
base stations for the purpose of evaluating
human exposure (IEC 62232:2017)**

National foreword

This British Standard is the UK implementation of EN 62232:2017. It is identical to IEC 62232:2017. It supersedes BS EN 50383:2010, BS EN 50400:2006+A1:2012, BS IEC 62232:2011 and BS EN 50492:2008+A1:2014, which are withdrawn.

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English Version

Determination of RF field strength, power density and SAR in the
vicinity of radiocommunication base stations for the purpose of
evaluating human exposure
(IEC 62232:2017)

Détermination des champs de radiofréquences, densité de
puissance et du DAS aux environs des stations de base
utilisées pour les communications radio dans le but
d'évaluer l'exposition humaine
(IEC 62232:2017)

Bestimmung der HF-Feldstärke, der Leistungsdichte und
der spezifischen Absorptionsrate (SAR) in der
Nachbarschaft von Funkkommunikations-Basisstationen zur
Ermittlung der menschlichen Exposition
(IEC 62232:2017)

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European Committee for Electrotechnical Standardization
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European foreword

The text of document 106/397/FDIS, future edition 2 of IEC 62232, prepared by IEC/TC 106 "Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62232:2017.

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standard or by endorsement
- latest date by which the national (dow) 2020-09-27
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This document supersedes EN 50400:2006 + AC:2011 + A1:2012, EN 50383:2010 + AC:2013 and EN 50492:2008 + A1:2014.

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The text of the International Standard IEC 62232:2017 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

ISO/IEC 17025	NOTE	Harmonized as EN ISO/IEC 17025.
CISPR 16-4-2	NOTE	Harmonized as EN 55016-4-2.

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 62209-1	-	Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures - Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)	EN 62209-1	-
IEC 62209-2	-	Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures - Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)	EN 62209-2	-
IEC 62479	-	Assessment of the compliance of low power electronic and electrical equipment with the basic restrictions related to human exposure to electromagnetic fields (10 MHz to 300 GHz)	EN 62479	-
IEC 62311	-	Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz - 300 GHz)	EN 62311	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

DETERMINATION OF RF FIELD STRENGTH, POWER DENSITY AND *SAR* IN THE VICINITY OF RADIOCOMMUNICATION BASE STATIONS FOR THE PURPOSE OF EVALUATING HUMAN EXPOSURE

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International Standard IEC 62232 has been prepared by IEC technical committee 106: Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure.

This second edition cancels and replaces the first edition published in 2011 and constitutes a technical revision.

The significant changes with respect to the previous edition are the following:

- a) Increased frequency range from 110 MHz to 100 GHz (including consideration of ambient sources 100 kHz to 300 GHz);
- b) product compliance – determination of compliance boundary information for an RBS product before it is placed on the market;
- c) product installation compliance – determination of the total RF exposure levels before the product is put into service;

- d) simplified document structure and methods of assessment for new technologies such as LTE-TDD, FDD and WiFi.

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 standard.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
106/397/FDIS	106/406/RVD

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

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document 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 document addresses the evaluation of radiofrequency (RF) field strength, power density or specific absorption rate (*SAR*) levels in the vicinity of radiocommunication base stations (RBS), also called product or Equipment Under Test (EUT), intentionally radiating in the frequency range 110 MHz to 100 GHz according to the scope (see Clause 1). It does not address the evaluation of current density which exposure guidelines often do not consider to be relevant when evaluating RF fields in the intended RBS operating frequency range.

This document specifies the RF exposure evaluation methods to be used for product compliance, product installation compliance and in-situ RF exposure assessments. It does not define human exposure limits, also called “exposure limits”. When implementing RF exposure assessments, the surveyor refers to the set of exposure limits applicable where exposure takes place.

Clause 2, Clause 3 and Clause 4 address normative references, terms and definitions, and symbols and abbreviated terms, respectively.

Clause 5 provides a quick start guide and details how to use this document.

Clause 6 describes the three main application areas of this document: RF exposure evaluation methods for product compliance, product installation compliance, and in-situ RF exposure assessments. Further details are provided in Annex C.

Clause 7 provides guidelines on how to select the evaluation method. Further details are provided in Annex A.

Clause 8 defines the RF exposure evaluation methods to be used and refers to further details in Annexes B and F.

Clause 9 addresses the estimation of uncertainty and refers to Annex E for further details.

Clause 10 describes reporting requirements for the evaluation or assessment.

Annexes and the bibliography are referenced extensively to provide useful clarifications or guidance.

Additional guidance can be found in IEC TR 62669 which includes a set of worked case studies giving practical examples of the application of this document.

DETERMINATION OF RF FIELD STRENGTH, POWER DENSITY AND *SAR* IN THE VICINITY OF RADIOCOMMUNICATION BASE STATIONS FOR THE PURPOSE OF EVALUATING HUMAN EXPOSURE

1 Scope

This document provides methods for the determination of radio-frequency (RF) field strength and specific absorption rate (*SAR*) in the vicinity of radiocommunication base stations (RBS) for the purpose of evaluating human exposure.

This document:

- a) considers intentionally radiating RBS which transmit on one or more antennas using one or more frequencies in the range 110 MHz to 100 GHz;
- b) considers the impact of ambient sources on RF exposure at least in the 100 kHz to 300 GHz frequency range;
- c) specifies the methods to be used for RF exposure evaluation for compliance assessment applications, namely:
 - 1) product compliance – determination of compliance boundary information for an RBS product before it is placed on the market;
 - 2) product installation compliance – determination of the total RF exposure levels in accessible areas from an RBS product and other relevant sources before the product is put into service;
 - 3) in-situ RF exposure assessment – measurement of in-situ RF exposure levels in the vicinity of an RBS installation after the product has been taken into operation;
- d) describes several RF field strength and *SAR* measurement and computation methodologies with guidance on their applicability to address both the in-situ evaluation of installed RBS and laboratory-based evaluations;
- e) describes how surveyors, with a sufficient level of expertise, establish their specific evaluation procedures appropriate for their evaluation purpose;
- f) provides guidance on how to report, interpret and compare results from different evaluation methodologies and, where the evaluation purpose requires it, determine a justified decision against a limit value;
- g) provides short descriptions of the informative example case studies given in the companion Technical Report IEC TR 62669 [1].

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 62209-1, *Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)*

IEC 62209-2, *Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)*

IEC 62479, *Assessment of the compliance of low power electronic and electrical apparatus with the basic restrictions related to human exposure to electromagnetic fields (10 MHz – 300 GHz)*

IEC 62311, *Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz – 300 GHz)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

ambient field

background electromagnetic field in the frequency range from at least 100 kHz to 300 GHz other than the emissions from the EUT in the frequency range 110 MHz to 100 GHz

3.2

antenna factor

ratio of the electromagnetic field strength incident upon an antenna to the voltage (U) that is produced across a specified impedance (e.g. 50 Ω) terminating the line connection of the antenna

3.3

assessment

undertaking of an assessment in order to arrive at a judgement based on evidence, of the suitability of RF exposure induced by a product with regards to RF exposure limits

3.4

assessment configuration

set of parameters which together represent the RBS configuration to be assessed according to the evaluation purpose, e.g. for conformity assessment

3.5

average absorbed power

time-averaged absorbed power

ohmic power dissipated in a volume V given by

$$P_A = \int_V \sigma [E(x, y, z)]^2 dV$$

where

$E(x, y, z)$ is the r.m.s. value of the electric field strength in the tissue in volts per metre;

σ is the electric conductivity of the tissue in siemens per metre

3.6**average transmitted power****time-averaged transmitted power**

rate of transmitted energy transfer expressed in watts given by

$$\overline{P}_{\text{avg}} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} P(t) dt$$

where

t_1 is the start time of the observation in seconds;

t_2 is the stop time of the observation in seconds;

$P(t)$ is the instantaneous transmitted power in watts

Note 1 to entry: The transmitted power is the conducted power applied to the antenna input connector minus the reflected power at the antenna input connector and minus the power dissipated as heat within the antenna.

3.7**basic restriction**

restriction on human exposure to time-varying electric, magnetic, and electromagnetic fields that is based on the applicable exposure guidelines

Note 1 to entry: For this document, the physical quantity used as a basic restriction is the specific absorption rate (SAR) or power density (S) depending on the frequency and defined by the relevant compliance standard.

3.8**base station****radio base station****BS**

fixed equipment including the radio transmitter and associated antenna(s) as used in wireless telecommunications networks

EXAMPLE Base stations for mobile communications, radio-relays, wireless local area network access points, base stations for cordless telephony, etc. that are not normally used in close proximity (i.e. within 20 cm) to the human body.

Note 1 to entry: Examples of wireless telecommunications networks include those used in mobile telecommunication systems according to ITU-R M.1224-1 [2], wireless local area networks, public safety networks and fixed wireless systems (including radio-relay systems, point-to-point communication and point-to-multipoint communication according to ITU-R F.592-4 [3] and ITU-R F.1339-1 [4]).

Note 2 to entry: Equipment for radar, TV and radio broadcast services are not considered to be an RBS.

3.9**collinear array antenna**

antenna consisting of a linear array of radiating elements, usually dipoles, with their axes lying in a straight line

3.10**compliance boundary****CB**

surface of arbitrary shape defining a volume outside of which the applicable limit condition is not exceeded

3.11**compliance distance**

distance from the antenna to the compliance boundary for a stated direction and set of transmission conditions

Note 1 to entry: In the absence of qualifying direction, the compliance distance is the maximum distance from the antenna to the compliance boundary.

3.12

control boundary

set of locations which together define where human access to a compliance boundary is limited by either warnings or physical controls

3.13

lower detection limit

minimum quantifiable response of the measuring equipment

3.14

upper detection limit

maximum quantifiable response of the measuring equipment

3.15

directivity

D

<of an antenna, in a given direction> ratio of the radiation intensity produced by an antenna in a given direction to the value of the radiation intensities averaged in all directions in space

Note 1 to entry: If no direction is specified, the direction of maximum radiation intensity from the given antenna is implied.

Note 2 to entry: The directivity is independent of antenna losses and equal to the absolute gain in the same direction if the antenna has no internal losses.

Note 3 to entry: The ratio can also be expressed in decibels.

3.16

dish antenna

parabolic antenna usually used for radio-relays or point-to-point communications

Note 1 to entry: See ITU-R F.592-4 [3] and ITU-R F.1339-1 [4].

3.17

duty factor

ratio of the sum of pulse durations to a stated averaging time

Note 1 to entry: For waveforms showing periodical behaviour, the averaging time is assumed to be the minimum repetition interval of a waveform frame, e.g. the pulse repetition period for single-pulse TDMA waveforms.

3.18

dynamic range

quotient of the signal from the maximum measurable indication of a quantity divided by the signal from the minimum measurable value of that quantity

Note 1 to entry: In some cases, the dynamic range can be expressed as an interval of the above-mentioned corresponding values.

[SOURCE: IEC 60050-394:2007, 394-40-17 [5]]

3.19

electric field strength

vector field quantity E which exerts on any charged particle at rest a force F equal to the product of E and the electric charge Q of the particle:

$$F = QE$$

[SOURCE: IEC 60050-121:1998, 121-11-18 [6]]

3.20**equivalent isotropic radiated power***EIRP*

<in a given direction> product of the radiofrequency input power to an antenna and the absolute gain of the antenna in a given direction

[SOURCE: IEC 60050-712:1992, 712-02-51 [7], modified – In the term, "isotropically" has been replaced by "isotropic"; in the definition, "power supplied" has been replaced by "radiofrequency input power".]

3.21**evaluation**

process of determining a value of an exposure metric

3.22**evaluation configuration**

set of parameter values which together represent the RBS configuration used in the evaluation

3.23**evaluation location**

specific physical location at which a single field parameter value has been measured or computed

Note 1 to entry: In the case of spatial averaging, this is the reference location defined in the averaging scheme.

3.24**exposure ratio***ER*

<at a given location and for each operating frequency of the BS> ratio of the exposure metric and the relevant exposure limit, both expressed in terms of power

EXAMPLE $ER = S/S_{lim}$, $ER = \max[(E/E_{lim})^2, (H/H_{lim})^2]$

Note 1 to entry: The exposure ratio can also be expressed as a percentage, i.e. $ER \% = ER$ (dimensionless) $\times 100 \%$.

3.25**field strength**

<of a radio transmitter> magnitude of the electromagnetic (electric or magnetic) field created at a given point by a radio transmitting system operating at a specified characteristic frequency with specified installation and modulation conditions

[SOURCE: IEC 60050-705:1995, 705-08-31 [8]]

3.26**frequency response**

curve representing the variations, with respect to frequency, of the indicated level of the exposure metric as a measuring instrument response to a known exposure metric

3.27**gain***G*

<of an antenna, in a given direction> ratio of the radiation intensity produced by an antenna in a given direction to the value of the radiation intensities averaged in all directions in space reduced by a factor representing the antenna losses

Note 1 to entry: If no direction is specified, the direction of maximum radiation intensity from the given antenna is implied.

Note 2 to entry: The ratio can also be expressed in decibels.

3.28

general public

all persons not classified as worker

3.29

intended use

reasonably foreseeable use of an RBS for the purpose intended, over its full range of applicable functions, in accordance with the instructions provided by the manufacturer, including installation and operation instructions

3.30

linearity

deviation from a straight line of the curve representing the output quantity as a function of the input quantity

[SOURCE: IEC 60050-394:2007, 394-40-31 [5]]

3.31

localized exposure

maximum value of exposure averaged over a small volume or area as defined by applicable RF exposure guidelines

3.32

magnetic field strength

magnetizing field strength

vector quantity obtained at a given point by subtracting the magnetization M from the magnetic flux density B divided by the magnetic constant μ_0 :

$$H = \frac{B}{\mu_0} - M$$

Note 1 to entry: In vacuum, the magnetic field strength is at all points equal to the magnetic flux density divided by the magnetic constant:

$$H = \frac{B}{\mu_0}$$

Note 2 to entry: The rotation of the magnetic field strength is the total current density J_t :

$$\text{rot } H = J_t$$

Note 3 to entry: The magnetic flux density B is sometimes called “magnetic field”, risking confusion with the magnetic field strength H .

[SOURCE: IEC 60050-121:1998, 121-11-56 [6]]

3.33

measurement drift

power drift

gradual deviation over time from a reproducible reading of the measured value

3.34

partial-body exposure

localized exposure of part of the body, as distinct from a whole-body exposure

3.35

peak spatial-average SAR

maximal value of SAR averaged within a specific mass

3.36**planar array**

<antenna> array in which corresponding points of the radiating elements lie in a plane

[SOURCE: IEC 60050-712:1992, 712-01-07 [7]]

3.37**plane wave equivalent power density**

<of an electromagnetic wave> power density equal in magnitude to the power density of a plane wave

3.38**power density**

power passing through a surface normal to the direction of propagation of energy of an electromagnetic wave divided by the area of the surface

3.39**probe isotropy**

degree to which the response of an electric field or magnetic field probe is independent of the polarization and direction of propagation of the incident wave

3.40**RF field strength**

electric field strength and/or magnetic field strength from an RF source

3.41**spatial-peak**

<value> non-spatially averaged peak value of the electric field, magnetic field, or power density

3.42**specific absorption rate**

SAR

time derivative of the incremental electromagnetic energy (dW) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dV) of given mass density (ρ)

$$SAR = \frac{d}{dt} \left(\frac{dW}{dm} \right) = \frac{d}{dt} \left(\frac{dW}{\rho dV} \right)$$

Note 1 to entry: *SAR* can be obtained using the following equation:

$$SAR = \frac{\sigma E^2}{\rho}$$

where

SAR is the specific absorption rate in watts per kilogram (W/kg);

E is the r.m.s. value of the electric field strength in the tissue in volts per metre;

σ is the electric conductivity of the tissue in siemens per metre;

ρ is the density of the tissue in kilograms per cubic metre.

3.43**source****RF source**

electronic equipment intentionally transmitting an RF signal

3.44

source-environment plane

method to define the evaluation regions to be considered in the evaluation point selection based on environmental complexity and distance from the source

3.45

source region

spatial volume surrounding an antenna, divided into three regions according to the impact the field characteristics have on the evaluation of the RF field strength, power density or *SAR*

Note 1 to entry There are two source regions near the antenna, called source region I and source region II, and one at a larger distance, called source region III.

3.46

surveyor

person(s) responsible for planning, executing and reporting on the evaluation of RF field strength, power density or *SAR* levels

3.47

whole-body exposure

exposure averaged over the whole body, on reference location defined in the averaging scheme

3.48

worker

adult who is generally exposed to RF fields under known conditions and is trained to be aware of potential risks and to take appropriate precautions

4 Symbols and abbreviated terms

4.1 Physical quantities

The internationally accepted SI units are used throughout this document.

Symbol	Quantity	Unit	Dimensions
α	Attenuation coefficient	reciprocal metre	m^{-1}
B	Magnetic flux density	tesla	$\text{T}, \text{V s m}^{-2}$
c_h	Specific heat capacity	joule per kilogram per kelvin	$\text{J kg}^{-1} \text{K}^{-1}$
E	Electric field strength	volt per metre	V m^{-1}
f	Frequency	hertz	s^{-1}
H	Magnetic field strength	ampere per metre	A m^{-1}
J	Current density	ampere per square metre	A m^{-2}
T	Temperature	kelvin	K
ε	Permittivity	farad per metre	F m^{-1}
λ	Wavelength	metre	m
μ	Permeability	henry per metre	H m^{-1}
S	Power density	watts per square metre	W m^{-2}
Ω	Resistance	ohm	V A^{-1}
ρ	Mass density	kilogram per cubic metre	kg m^{-3}
σ	Electric conductivity	siemens per metre	S m^{-1}

NOTE 1 In this document, temperature is quantified in degrees Celsius, as defined by: $T (^{\circ}\text{C}) = T (\text{K}) - 273,16$.

NOTE 2 Annex A and B.2 define additional symbols and variables used in this document.

4.2 Constants

Symbol	Physical constant	Magnitude
c	Speed of light in vacuum	$2,997\,9 \times 10^8 \text{ m s}^{-1}$
η_0	Impedance of free space	$376,730\,3 \, \Omega$ (approximately $120\pi \, \Omega$)
ε_0	Permittivity of free space	$8,854\,188 \times 10^{-12} \text{ F m}^{-1}$
μ_0	Permeability of free space	$4\pi \times 10^{-7} \text{ H m}^{-1}$

4.3 Abbreviated terms

ADB	assessment domain boundary
AMPS	Advanced Mobile Phone System
BCCH	broadcast control channel
BS	base station
CB	compliance boundary
CDD	cyclic delay diversity
CDMA	code division multiple access
CP	cyclic prefix
CPICH	common pilot channel
CRS	cell-specific reference signal
DECT	Digital Enhanced Cordless Telecommunications
DI	domain of investigation
DPCH	dedicated physical channel
ER	exposure ratio
EUT	equipment under test
FDD	frequency division duplex
FDMA	frequency division multiple access
FDTD	finite difference time domain
FEM	finite element method
FIT	finite integration technique
GSM	Global System for Mobile communications (originally <i>Groupe Spécial Mobile</i>)
HPBW	half power beamwidth
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IP	Internet Protocol
LTE	Long Term Evolution
MAC	Media Access Control
MoM	method of moments
NMT	Nordic Mobile Telephone
OFDM	orthogonal frequency division multiplexing
P-SS	Primary Synchronization Signal
PBCH	Physical Broadcast Channel

PML	perfectly matched layer
PRACH	Physical Random Access Channel
RB	resource block
RBS	radiocommunication base station
RBW	resolution bandwidth
RE	resource element
RF	radio frequency
r.m.s.	root mean square
r.s.s.	root sum square
RS	reference signal
S-SS	Secondary Synchronization Signal
SA	spectrum analyser
SD	separation distance
TCP	Transmission Control Protocol
TDMA	time division multiple access
<i>TER</i>	total exposure ratio
TETRA	Terrestrial Trunked Radio
UDP	User Datagram Protocol
UMTS	Universal Mobile Telecommunications System
USDC	United States Digital Cellular
WCDMA	wideband code division multiple access
Wi-Fi® ¹⁾	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access

5 Quick start guide and how to use this document

5.1 Overview

Given the different types of evaluation methods of human exposure to EMF and their inherent complexities, this document contains a significant amount of technical detail. While such detail is necessary, care has been taken to layer the presentation of information, with content broadly separated into process, detail and additional information.

In Clause 5, high-level process information is provided from two perspectives: 5.2 outlines the structure of the document as applied to conducting an evaluation; and 5.3 is a high-level application based approach to applying the document to situations such as the determination of a compliance boundary.

5.2 Quick start guide

The quick start guide provides an overview of the evaluation process as a flow chart.

¹⁾ Wi-Fi® is a trademark of the Wi-Fi Alliance. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC. While officially the term does not mean anything, it is typically used to describe Wireless Local Area Networks such as IEEE 802.11b/g/n/ac.

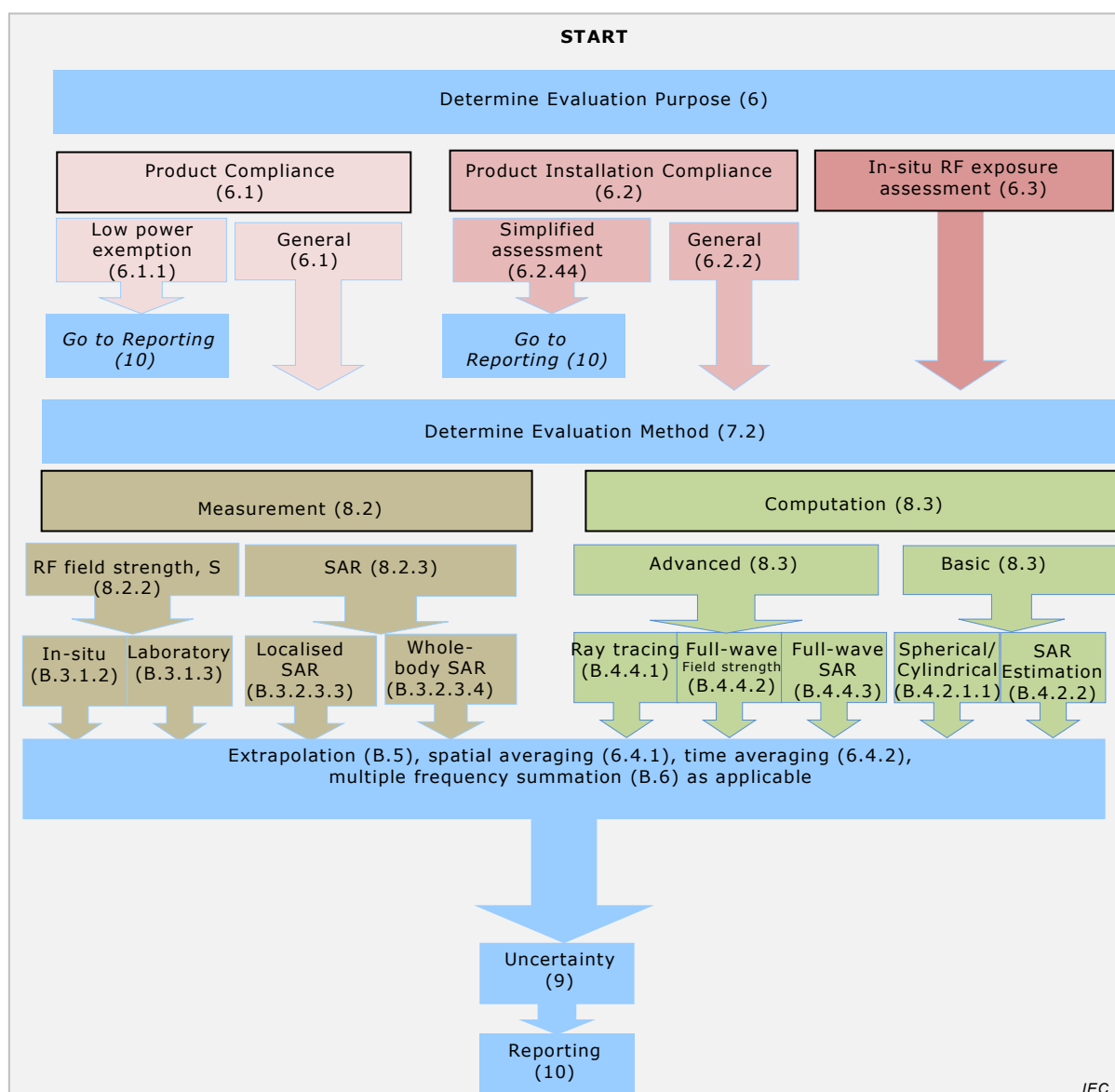


Figure 1 – Quick start guide to the evaluation process

The quick start guide shown in Figure 1 outlines the evaluation process along with the evaluation steps explained in Table 1. This sequence involves determining the evaluation purpose, method(s) of evaluation, as well as extrapolation, spatial averaging, time averaging and multiple frequency summation. The uncertainty and reporting stages complete the evaluation process. Report template is defined in 10.2. Worked case studies are introduced in 5.4.

Table 1 – Quick start guide evaluation steps

Stage	Evaluation steps	Action
Determine Evaluation Purpose (Clause 6)	Determine the purpose of the evaluation: – Product compliance – Product installation compliance, or – In-situ RF exposure evaluation	Confirm purpose of evaluation
RF exposure evaluation process (Clause 6)	Determine the applicable process to be used for the chosen evaluation purpose.	Run the evaluation process
Determine Evaluation Method (7.2)	Determine if a simplified evaluation process is applicable. Otherwise, select either a measurement or computation evaluation method, or both if required. Evaluation methods are ranked, and in general a higher ranked method takes precedence. However, lower ranking evaluations are valid within their applicability and may be more practical to implement, depending on cost, feasibility, and resource availability.	Select evaluation method
Measurement (8.2)	Determine applicable measurement procedures: – laboratory or in-situ measurement – <i>SAR</i> or RF field strength (broadband or narrowband) measurements	Select relevant measurement procedures if applicable
Computation (8.3)	Determine applicable computation methods. For example, a simple peak RF field strength evaluation, which is conservative, may be used. Even though higher ranking evaluation methods shall take precedence, they depend on the detailed information about the source and environment, as well as the availability of software packages capable of modelling such complexities.	Select relevant computation procedures if applicable
Extrapolation (B.5)	Determine if extrapolation is required. Where the test configuration differs from the required final evaluation configuration, an extrapolation factor will be required to adjust evaluated results (RF field strength, power density or <i>SAR</i>).	Determine extrapolation factor and apply to results
Summation (B.6)	Determine if the evaluation requires summation of combined exposure. Summation of combined RF field strength, power density or <i>SAR</i> value is required either when a single source emits RF fields on multiple frequency bands or when evaluating RF fields from multiple sources.	Sum test results if required
Uncertainty (Clause 9)	Any measurement or computation can only approximate the exposure metric within the uncertainty tolerance, and so a quantitative statement of uncertainty is required.	Determine uncertainty and complete the uncertainty table when applicable
Reporting (Clause 10)	The final report describes the results of the evaluation, provides sufficient technical details to allow for repeatability, and interprets the results by comparison with the relevant limit, if required.	Prepare final report and consider the report template in IEC TR 62669

5.3 How to use this document

There are three main applications of RF exposure evaluation defined in this document.

- 1) Product compliance: determination of compliance boundary information for an RBS product before it is placed on the market (see 6.1).
- 2) Product installation compliance: determination of the total RF exposure levels in accessible areas from an RBS product and other relevant sources before the product is put into service (see 6.2).
- 3) In-situ RF exposure assessment: measurement of RF exposure levels in the vicinity of an RBS installation after the product has been installed and is operating (see 6.3).

Clause 7 provides guidelines on how to select the evaluation method.

NOTE National regulatory agencies can have different requirements which override those specified by this document.

5.4 Worked case studies

A separate IEC Technical Report, IEC TR 62669 [1], contains worked evaluation examples of typical RBS sites using a range of methods described in this document. The example sites include roof-tops, towers, poles, small cells and in-building cells.

Each case study has been chosen to illustrate typical RBS sites and common evaluation tasks. Some of the case studies demonstrated multiple evaluation methods. However, in most scenarios, only one method would be required to complete an evaluation.

NOTE IEC TR 62669 was developed to address IEC 62232:2011. A new version of IEC TR 62669 is currently under development to reflect the updated evaluation procedures in this document.

6 Evaluation processes for product compliance, product installation compliance and in-situ RF exposure assessments

6.1 Evaluation process for product compliance

6.1.1 General

A manufacturer or other legal entity that will place an RBS product on the market is typically required to provide RF exposure information, including relevant compliance boundaries (exclusion zones), to the end user of the product. The compliance boundary shall be established for applicable RF exposure limits using RF field strength, power density or *SAR* assessment methods as described in 6.1.5.

Compliance boundary information is normally determined for a number of selected typical configurations (frequency band, number of transmitters, bandwidth, antenna, feeder, etc.) of the RBS product, assuming free-space conditions, and at the maximum power for each configuration.

NOTE Establishing compliance boundaries can be one of a range of requirements or methods that relate to product compliance.

Where a product complies with IEC 62479 and it applies depending on whether the applicable national regulatory agency recognizes it, then no compliance boundary is required. Otherwise, the compliance boundary shall be assessed according to 6.1.2 to 6.1.5.

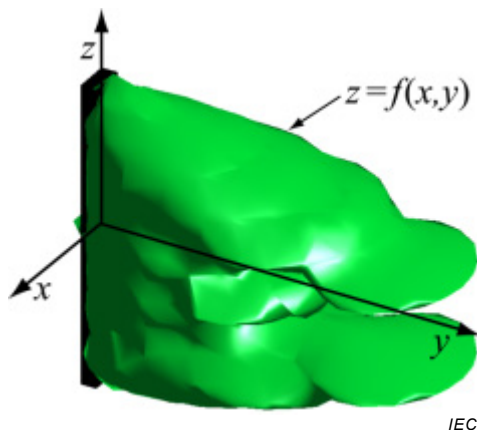
6.1.2 Establishing compliance boundaries

The criteria defined in Table 3 and Clause 8 shall be used to select the exposure metric.

SAR or power density (depending on the frequency range) measurements are the most appropriate evaluation technique to determine accurate compliance boundary (CB) information for equipment designed for small stand-alone equipment/devices and multi-element base station antennas shorter than or equal to 1,5 m (see 8.2.2 and B.3.2). Examples of this type of equipment include medium range, local area, or home BS, picocell and microcell equipment 3GPP TS 25.104 [9], 3GPP TS 36.104 [10]. Alternatively, *SAR* can be calculated using estimation formulas or using advanced computational methods (see B.4.2.2 and B.4.4.3, respectively).

For all RBS products, in particular macrocell equipment but also small coverage area equipment, field strength or power density evaluations are applicable. Either laboratory measurements or computations may be used. (see B.3.1.3 and B.4, respectively). Alternatively, *SAR* can be calculated using estimation formulas or using advanced computational methods (see B.4.2.2 and B.4.4.3, respectively).

The most accurate (smallest) compliance boundary is obtained as an iso-surface, with the iso-surface value given by the applicable RF exposure limit (see Figure 2).



In this case the shape of the compliance boundary shall be accurately described, e.g. in terms of a mathematical function $z = f(x, y)$.

The iso-surface compliance boundary defined in 6.1.3 may be enclosed in simpler shaped volumes to define more conservative compliance boundaries. Valid compliance boundary shapes are not limited to these examples.

In Figure 3 cases (a) and (b), two circular cylindrical compliance boundaries are illustrated for a sector coverage antenna and a horizontally omnidirectional antenna, respectively.

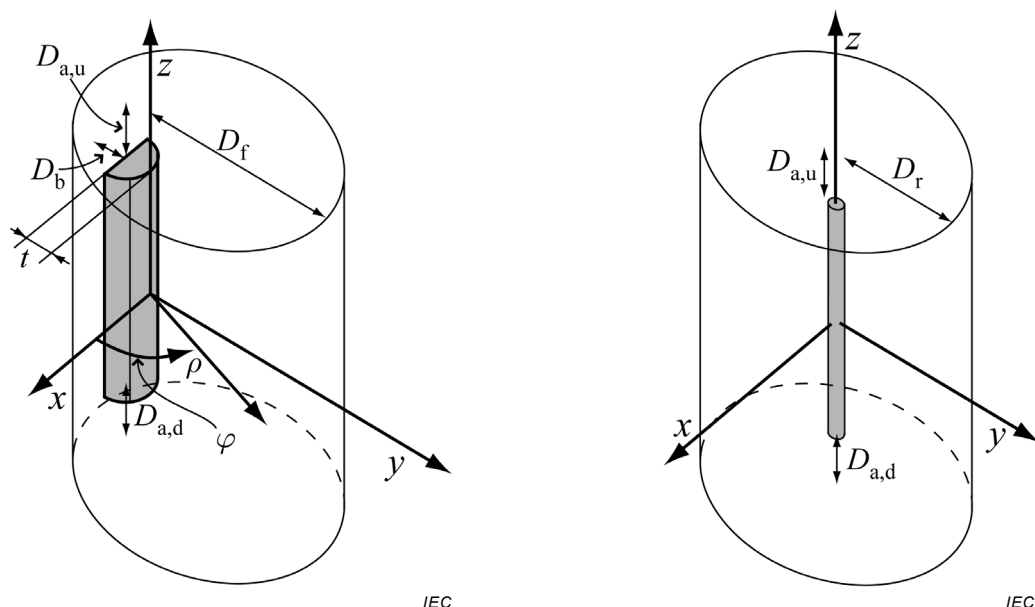


Figure 3 – Example of circular cylindrical compliance boundaries

The compliance boundary for the sector coverage antenna is described in terms of D_f , D_b , $D_{a,d}$, $D_{a,u}$, and the antenna height and thickness according to Figure 3. Note that for the sector coverage antenna the distances D_f and D_b shall be determined so that the aforementioned iso-surface will be completely inscribed by the cylinder. In a similar way, the compliance boundary for the horizontally omnidirectional antenna is described in terms of D_f , $D_{a,d}$, $D_{a,u}$, and the height and radius of the antenna.

The box shaped compliance boundary shown in Figure 4 can be used for directional antennas, for example a panel antenna. In this case the boundary is described in terms of D_f , D_b , $D_{a,d}$, $D_{a,u}$, D_s , and the dimensions of the antenna.

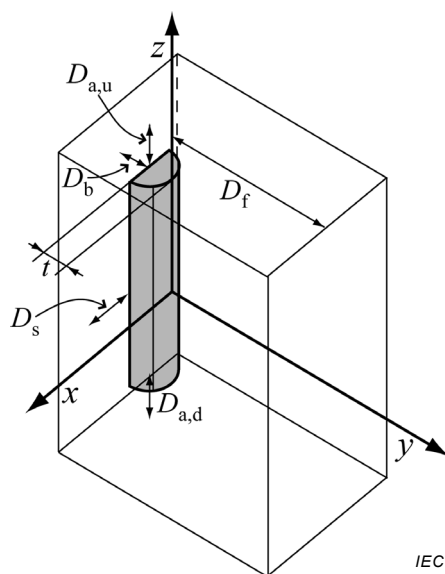


Figure 4 – Example of box shaped compliance boundary

In order to take into account the horizontal beamwidth of the antenna, the box shape may be truncated with 45° cut plane on the edges near the panel antenna. The truncated box shaped compliance boundary is described in Figure 5, which is defined by the truncation distance D_t in addition to the parameters of the box shaped compliance boundary (see Figure 4).

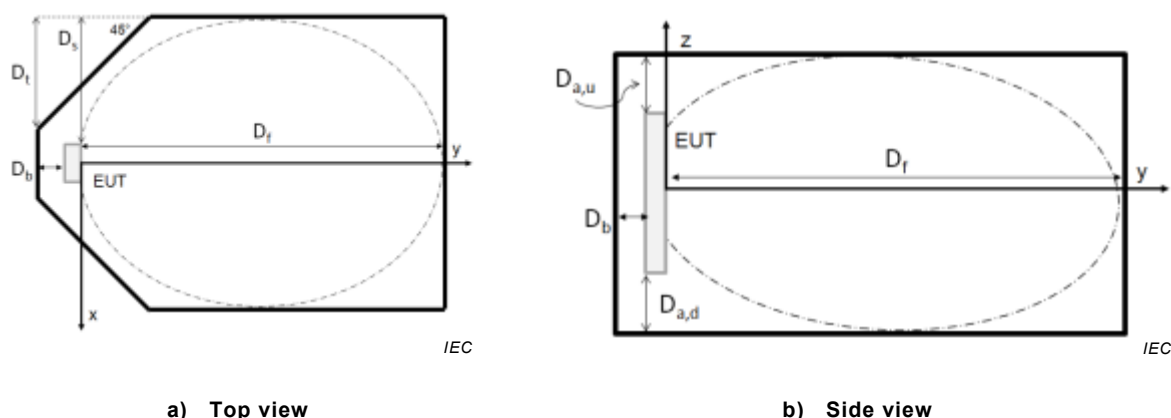
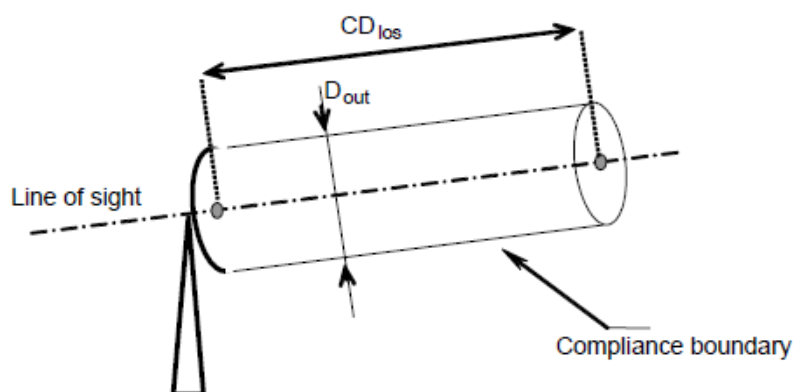


Figure 5 – Example of truncated box shaped compliance boundary

For parabolic or dish antennas, the compliance boundary defined in Figure 7 and in F.11 can be used.



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Figure 6 – Example of dish antenna compliance boundary (from [11])

6.1.5 Methods for establishing the compliance boundary

6.1.5.1 General

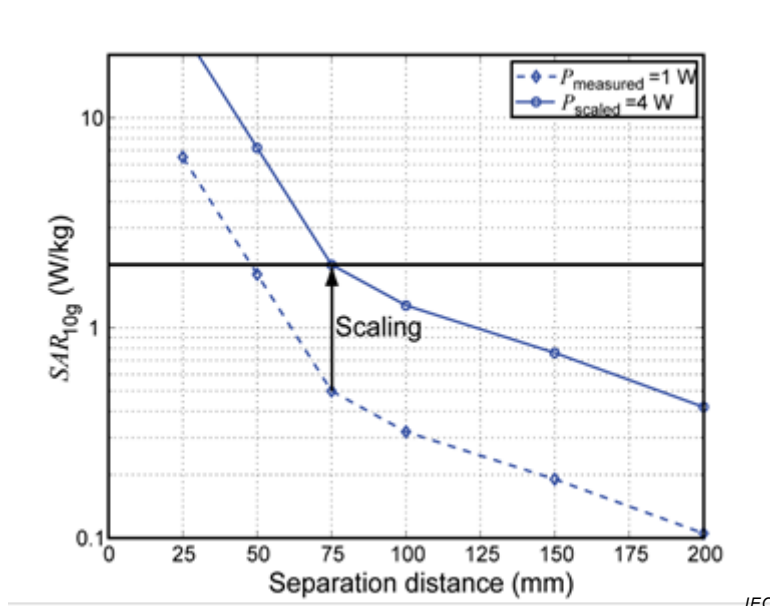
The compliance boundary shall be established according to 6.1.5.2 to 6.1.5.7 using evaluation methods defined in Clause 8 and Annex B.

6.1.5.2 Establishing compliance boundary using RF field strength measurements

Cylindrical or box shaped or truncated box shaped compliance boundaries shall be generated by measuring the RF field strength in suitable directions with respect to the transmitting antenna (e.g. front, back, side, and above/below), and then comparing the obtained RF field strength with applicable exposure limits (RF field strength or power density) (see B.3.1.3).

6.1.5.3 Establishing compliance boundary using *SAR* measurements

Cylindrical or box shaped or truncated box shaped compliance boundaries shall be generated by measuring *SAR* for suitable antenna orientations as a function of distance using the measurement procedure in B.3.2. By linear scaling of the *SAR* versus separation distance curve, compliance distances for different power levels shall be obtained by comparing the results with applicable exposure limits as illustrated in Figure 7.



NOTE Scaling to determine the compliance distance at a power level of 4 W, when the SAR measurements were performed at a power level of 1 W for a peak spatial-average SAR exposure limit of 2 W/kg over an averaging mass of 10 g.

Figure 7 – Example illustrating the linear scaling procedure

The scaled SAR values are computed from the measured by multiplying with the ratio between the scaled and the measured power levels. The compliance distance is then obtained from the figure by determining where the scaled SAR curve intersects with the pertinent SAR limit value.

6.1.5.4 Establishing compliance boundary using cylindrical and spherical formulas

The power density or field strength shall be calculated in a region surrounding the base station antenna for the maximum possible transmitted power using the formulas defined in B.4.2.1.1. Based on this evaluation, compliance boundaries in the form of various solids as described in 6.1.4 (sphere, cylinder or box) can be determined.

Alternatively, the basic algorithm defined in B.4.3 can be used to obtain an iso-surface compliance boundary by using the applicable RF exposure limit as the iso-surface value. Simpler and more conservative compliance boundaries can be obtained by inscribing the obtained iso-surface in various solids as discussed in 6.1.4.

6.1.5.5 Establishing compliance boundary using SAR estimation formulas

Cylindrical compliance boundaries (see Figure 3) shall be generated for sector coverage and horizontally omnidirectional antennas operating in the frequency range 700 MHz to 2 700 MHz by using the SAR estimation formulas of B.4.2.2 and applicable RF exposure limits according to the procedure described in [12]. For sector coverage antennas, the diameter of the cylinder is determined by the compliance distances in the front and back directions together with the antenna thickness t (see Figure 3a)). For horizontally omnidirectional antennas, the radius of the cylinder is determined by the main beam compliance distance and the radius of the antenna. The height of the cylinder is obtained by first multiplying the axial compliance distance with a factor of 2 (above and below antenna) and then adding the height of the antenna.

When implementing SAR estimation formulas for box shaped and truncated box shaped compliance boundaries, the SAR formulas defined in B.4.2.2 shall also be used.

6.1.5.6 Establishing compliance boundary using full wave analysis

After an accurate numerical model has been created following the procedure in B.4.4.2, the fields surrounding the base station antenna should be calculated for the maximum possible transmitted power. An iso-surface compliance boundary can then be obtained in a post-processing step by using the applicable RF exposure limit as the iso-surface value. Simpler and more conservative compliance boundaries can be obtained by inscribing the obtained iso-surface in various solids as discussed in 6.1.4.

6.1.5.7 Establishing compliance boundary for dish antennas

The compliance boundary is a cylinder and the compliance distance shall be established using the formula defined in F.11.

6.1.6 Uncertainty

Uncertainty analysis shall be performed according to Clause 9.

6.1.7 Reporting

Reporting shall be performed according to Clause 10. The RF exposure assessment report used for product compliance shall contain at least the following:

- Description of the EUT:
 - name, reference (e.g. serial number), technologies;
 - maximum transmitted power for each transmit frequency band;
 - antenna characteristics (gain, horizontal and vertical beamwidth) for each transmit frequency band, total *EIRP*, and, if the product is used with external antennas, a detailed description of at least one typical configuration², including antenna system (feeders, connectors, combiners, etc.);
- Description of the evaluation method and the exposure metric (*SAR*, *S*, *E* or *H*), the rationale for the choice (see Clause 7) and the relevant technical information required for repeatability and for documentation of the validity of the method, including:
 - for measurements:
 - probe(s) and measurement instrument(s) used, including characteristics, calibration details, and probe correction factors;
 - results of system validation check;
 - test setup and measurement conditions (temperature, etc.);
 - for calculations:
 - name and version of the calculation/simulation tool (if applicable);
 - limitations for the calculation/simulation tool (e.g. frequency range, near-field/far-field, etc.);
 - uncertainty analysis.
- Description of the compliance boundary:
 - compliance boundary shape (see 6.1.4);
 - compliance boundary dimensions for the relevant range of RF transmit powers, frequency bands, technologies and applicable exposure limits.
- Description of installation guidelines for the EUT, where relevant.

² Actual product installation parameters are reported according to 6.2.9.

6.2 Evaluation process used for product installation compliance

6.2.1 General

A network operator or other legal entity intending to put an RBS product into operation usually needs to evaluate the RF field strength levels; typically these evaluations are performed in accessible areas and in the vicinity of the base station, to verify compliance with relevant RF exposure limits and regulations. In such an evaluation, contributions from other relevant sources and possible effects of the environment need to be considered. Reasonable endeavours should be undertaken to consider other relevant sources.

The RF exposure levels from the RBS product and other relevant sources shall be determined at maximum transmit power of the equipment (theoretical or actual, see B.5) using measurements (see B.3.1.2) or computations (see B.4). Contributions from multiple sources shall be determined using summation formulas (see B.6).

6.2.2 General evaluation procedure for product installations

Where a new product is installed, the procedure described in Figure 8 shall be used to evaluate the RF exposure, taking into account other RF sources in the vicinity. In order to allow for accurate and efficient evaluations, different routes are possible depending on the characteristics of the product installation. In some specific cases, a simplified evaluation process of the product installation is possible without the necessity of conducting measurements or computations. Such a simplified evaluation process is defined in 6.2.4.

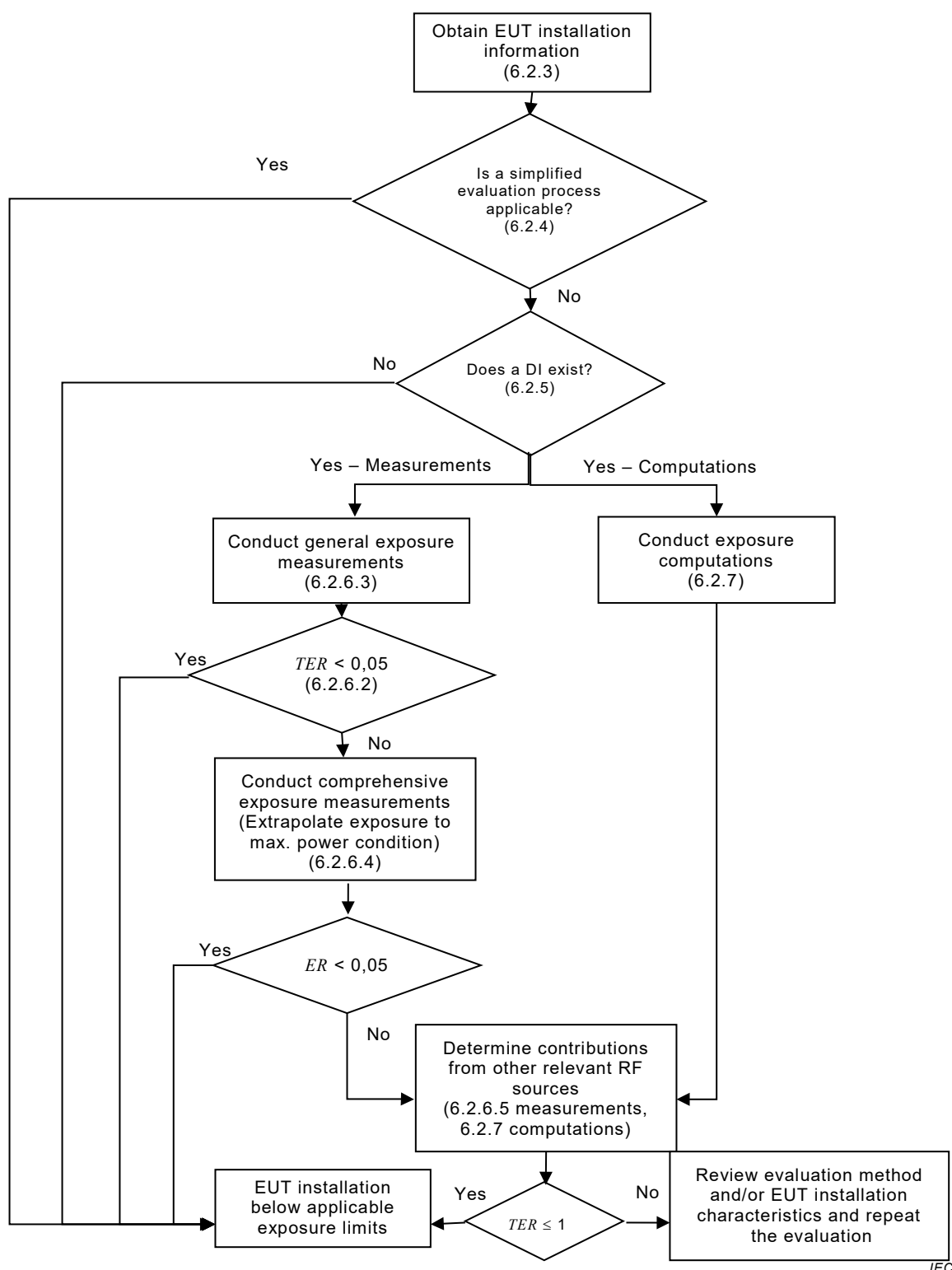


Figure 8 – Flowchart describing the product installation evaluation process

6.2.3 Product installation data collection

The following information shall be obtained for the product installation:

- maximum transmitted power for each transmit frequency band of the base station as installed;

- antenna characteristics (gain, horizontal and vertical beamwidth) for each transmit frequency band, total *EIRP*, and a detailed description of the configuration of the base station in its operational environment, including antenna system (feeders, connectors, combiners, etc.). If the product installation compliance has been assessed using the simplified evaluation process as defined in 6.2.4, then all parameters used to define the installation class in Table 2 shall be included;
- accessible area.

When comprehensive evaluations supporting extrapolation to maximum traffic is performed (see B.5) the following information is required:

- the reference name and frequency/bandwidth of any component of the whole signal which is to be used as a reference for extrapolation.
- the ratio between the component power level and the maximum power of the configuration to be extrapolated.

For example, the following information shall be used for GSM, WCDMA, and LTE:

- GSM: Central frequency of the broadcast channel (BCCH) and maximum number of carriers (channels) used by the product.
- WCDMA: Common pilot channel (CPICH) frequency and power level relative to total power.
- LTE: Centre frequency of the product channels and bandwidth.

6.2.4 Simplified product installation evaluation process

A simplified product installation process applies when no detailed measurements or computations are required to establish product installation compliance. The simplified evaluation process is based on easily accessible characteristics of the installation configuration, such as *EIRP*, direction of the main lobe, compliance boundary and installation positions of the transmitters/antennas with respect to accessible areas for the product and other relevant sources when applicable.

For the implementation of the simplified evaluation process, product specifications provided by the BS equipment and/or antenna manufacturer(s) shall be used, in particular transmitted power, antenna gain and compliance boundary dimensions evaluated in accordance with the requirements defined in 6.1.

Product installation evaluation is not required if the product complies with IEC 62479 or if the product compliance boundary dimensions are zero.

For products with antenna directivity of 30 dBi or above (e.g. dish antenna), product installation evaluation is not required if there is no access within the compliance boundary dimensions (see F.11). For such products, the antenna is usually installed to maintain line of sight conditions in order to prevent the radio link from being broken.

Product installation classes for which a simplified installation evaluation process is applicable can be developed based on applicable exposure limits. For example, the classes defined in Table 2 can be used with general public ICNIRP-based [13] exposure limits. The rationales used to establish those classes are presented in Annex C. If there are multiple equipment items co-located on the same site as the product, the *EIRP* criteria defined in Table 2 apply to the sum of *EIRP* of all co-located equipment.

Table 2 – Example of product installation classes where a simplified evaluation process is applicable (based on ICNIRP general public limits [13])

Class	<i>EIRP</i> ^a (W)	<i>EIRP</i> (dBm)	Product installation criteria
E0	n/a	n/a	The product complies with IEC 62479 or the product compliance boundary dimensions are zero. No specific requirement for product installation.
E2	≤ 2	≤ 33	The product is installed according to instructions from the manufacturer and/or entity putting into service. Compliance with the exposure limits is generally obtained at zero distance or within a few centimetres.
E10	≤ 10	≤ 40	The product is installed according to instructions from the manufacturer and/or entity putting into service and the lowest radiating part of the antenna(s) is at a minimum height of 2,2 m above the general public walkway.
E100	≤ 100	≤ 50	The product is installed according to instructions from the manufacturer and/or entity putting into service and: (a) the lowest radiating part of the antenna(s) is at a minimum height of 2,5 m above the general public walkway, (b) the minimum distance to areas accessible to the general public in the main lobe direction is D_m^b, and (c) there is no pre-existing RF source with <i>EIRP</i> above 10 W installed within a distance of 5 D_m metres in the main lobe direction (as determined by considering the half power beam width) and within D_m metres in other directions. D_m is the compliance distance in the main lobe assessed according to 6.1. If D_m is not available, a value of 2 m can be used or 1 m if all product transmit frequencies are equal to or above 1 500 MHz.^c
E+	> 100	> 50	The product is installed according to instructions from the manufacturer and/or entity putting into service and: (a) the lowest radiating part of the antenna(s) is at a minimum height of H_m metres above the general public walkway, (b) the minimum distance to areas accessible to the general public in the main lobe direction is D_m^b metres, and (c) there is no pre-existing RF source with <i>EIRP</i> above 100 W installed within a distance of 5 D_m metres in the main lobe direction and within D_m metres in other directions. D_m is the compliance distance in the main lobe assessed according to 6.1 and H_m is given by Equations (6.1), (6.2) or (6.3).^d
^a <i>EIRP</i> transmitted by the installed antenna(s) including all active bands. ^b D_m is also defined as D_f or D_r in 6.1.4. For E10, the installation height is derived from the <i>SAR</i> estimation formula provided in B.4.2.2 and realistic antenna configurations. For E100, the installation height is derived from the <i>SAR</i> estimation formula provided in B.4.2.2 and realistic antenna configurations and D_m values of 1 m and 2 m are derived from the far-field spherical formula (Equation (B.21) in B.4.2.1.1.2) using a ground reflection factor of 0. For E+, H_m and D_m defined in Equations (6.1), (6.2) or (6.3) are derived from the far-field spherical formula (Equation (B.21) in B.4.2.1.1.2) using a ground reflection factor of 1. ^c When such condition is not fulfilled, the installation is still compliant if the sum of the <i>EIRPs</i> of the EUT and nearby sources is less than 100 W. If the total <i>EIRP</i> is above 100 W then the EUT is still compliant if it is installed at a minimum height of H_m metres above the general public walkway and at a minimum distance from areas accessible to the general public in the main lobe direction of D_m metres, where H_m and D_m are obtained using Equations (6.1), (6.2) or (6.3) for the sum of the <i>EIRPs</i> including those of nearby sources. ^d When such condition is not fulfilled, the installation is still exempted from evaluations if the EUT is installed at a minimum height of H_m metres above the general public walkway and at a minimum distance from areas accessible to the general public in the main lobe direction of D_m metres, where H_m and D_m are obtained using Equations (6.1), (6.2) or (6.3) for the sum of the <i>EIRPs</i> including those of nearby sources.			

The frequency dependent equations (6.1) to (6.3) below are applicable for calculation of the minimum installation height H_m and the compliance distance in the main lobe D_m defined in Table 2. These equations were introduced in [14]. To be conservative, f shall be chosen as the lowest limit of all frequency bands of the EUT.

For frequencies between 100 MHz and 400 MHz:

$$H_m = \max \begin{cases} 2 + \sqrt{\frac{EIRP \cdot A_{sl}}{2\pi}} \\ 2 + \sqrt{\frac{EIRP}{2\pi}} \sin(\alpha + 1.129\theta_{bw}) \end{cases} \quad D_m = \sqrt{\frac{EIRP}{2\pi}} \quad (6.1)$$

For frequencies between 400 MHz and 2 000 MHz:

$$H_m = \max \begin{cases} 2 + \sqrt{\frac{EIRP \cdot 200 A_{sl}}{f\pi}} \\ 2 + \sqrt{\frac{200 \cdot EIRP}{f\pi}} \sin(\alpha + 1.129\theta_{bw}) \end{cases} \quad D_m = \sqrt{\frac{EIRP \cdot 200}{f\pi}} \quad (6.2)$$

For frequencies between 2 000 MHz and 100 000 MHz (i.e. 100 GHz):

$$H_m = \max \begin{cases} 2 + \sqrt{\frac{EIRP \cdot A_{sl}}{10\pi}} \\ 2 + \sqrt{\frac{EIRP}{10\pi}} \sin(\alpha + 1.129\theta_{bw}) \end{cases} \quad D_m = \sqrt{\frac{EIRP}{10\pi}} \quad (6.3)$$

where:

- f is the frequency of operation of the RBS in MHz;
- A_{sl} is the side lobe suppression value in linear scale;
- α is the downtilt in radians (both electric and mechanic);
- θ_{bw} is the vertical half power beamwidth in radians.

6.2.5 Assessment area selection

The domain of investigation (DI) represents the volume where an exposure evaluation and assessment shall be conducted. The DI is the part of the assessment domain boundary (ADB) of the equipment under test, where the people may have access. Access in this context refers to any part of the body being within the ADB under normal conditions. Outside the ADB, the exposure ratio from the product installation shall be less than 0,05.

NOTE Outside the ADB the product is not a relevant source, and an evaluation is not needed.

If the compliance boundary is available, the length D_{ad} (in metres) of the ADB in the main beam direction shall be 5 times the compliance distance. Alternatively:

- for a single band antenna the simplified expression provided in Equation (6.4) can be used. It is based on the free-space formula (Equation (B.21) in B.4.2.1.1.2) and provides a conservative estimation of the ADB in the shape of a box (Figure 9).

$$D_{ad} = \sqrt{\frac{EIRP}{0,05 S_{lim} 4\pi}} = 1,3 \cdot \sqrt{\frac{EIRP}{S_{lim}}} \quad (6.4)$$

where S_{lim} is the relevant power density exposure limit (W/m²).

- for multiband antennas having more than one active band, the ADB can be calculated using

$$D_{ad} = 1,3 \cdot \sqrt{\sum_i \frac{EIRP_i}{S_{lim,i}}}, \quad (6.5)$$

where $EIRP_i$ is the $EIRP$ of the product in band i and $S_{lim,i}$ is the relevant power density exposure limit (W/m^2) for band i .

The dimensions of the ADB, if determined using Equation (6.4) or (6.5), are largely overestimated in the vertical direction of the antenna. Therefore, the following rules shall be applied:

- Access regions placed H_b metres or more below the antenna mounting height (measured from the centre point of the antenna) shall not be considered as part of the ADB, where H_b is given by³

$$H_b = \max(D_{ad} \tan \alpha, 3,5) \quad (6.6)$$

Here, α is the antenna downtilt (mechanical and electrical) in radians. If α is not known it can be assumed to equal $\pi/15$ radians (12 degrees), which is a realistic maximum downtilt chosen to obtain a conservative result. The number 3,5 m was also chosen to correspond to a realistic maximum H_b for an antenna with no downtilt.

- General public access regions placed 3,5 m or more above the antenna mounting height (measured from the centre point of the antenna) shall not be considered as part of the ADB.

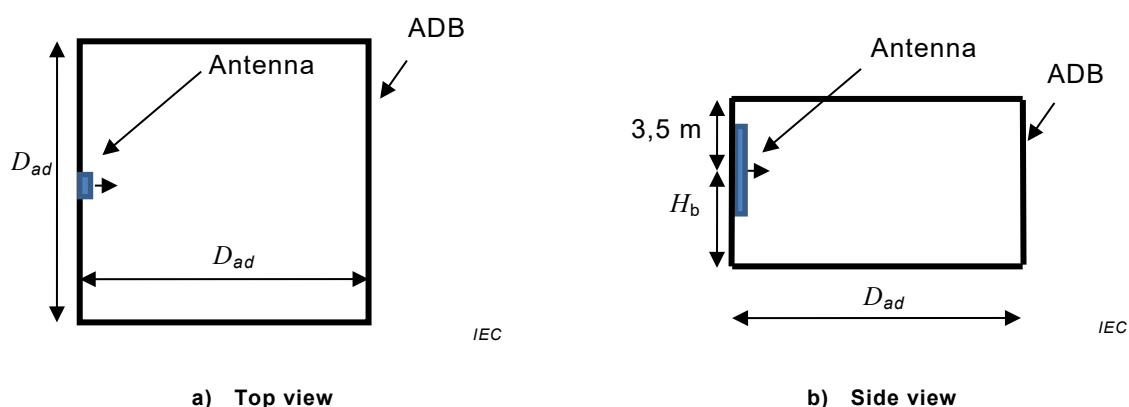
The equations above are applicable for down-tilted antennas. If the antenna is tilted upwards the values shall be swapped. In addition, for rooftop or wall installations, regions within the building on which the antenna is mounted shall be excluded from the ADB if the antenna main beam is pointing away from the building⁴.

Based on observations of the product installation and environment, as well as on experience gained by RF exposure evaluations of similar sites, the DI can be restricted to the points of maximum exposure.

If the general public has no access to the ADB, there is no DI and the product installation is compliant for general public access.

³ The first term in brackets corresponds to the height of the ADB given by the main beam for down-tilted antennas. The second term takes into consideration that for small tilt angles, the ADB in the vertical direction might be given by the antenna side lobe (or by the extension of the main lobe in the vertical plane). Since the maximum side lobe amplitude and direction might be difficult to estimate, a minimum height of 3,5 m is conservatively chosen.

⁴ Transmission in these directions corresponds to the side lobe of the antenna. In addition, the attenuation in the walls and roof can reduce the power density by 10 dB to 20 dB or more.



The ADB is oriented according to the antenna direction.

Figure 9 – Square-shaped assessment domain boundary (ADB) with size D_{ad}

6.2.6 Measurements

6.2.6.1 General

RF field strength measurements by means of both frequency selective or broadband equipment can be used to evaluate the product installation. The measurement system(s) and the post processing shall at least cover the frequency range from 100 kHz to 6 GHz and up to 300 GHz if required. Measurement equipment shall be chosen and operated according to B.3.1.2.

6.2.6.2 Determination of the total exposure ratio (TER)

The total level of exposure shall be calculated by summing the exposure ratios. This involves the extrapolated field strength E_i in each band used by the product and the relevant ambient sources (see 6.2.6.5). Where the general exposure evaluation has reported maximum field strength within the points of the DI, the following formula shall apply:

$$TER = \sum_{i=1}^N ER_i, \quad (6.7)$$

where ER_i is the exposure ratio for the band i .

6.2.6.3 General TER measurements

General TER evaluation consists of measurement of the total field strength over the entire frequency range of the product and relevant sources. Broadband equipment is suitable for this type of measurement. Frequency selective instruments can be used provided that the field strength is integrated over the entire bandwidth.

During general exposure evaluation, measurements shall be taken according to B.3.1.2.5 over the whole DI. Good practice is to move the probe slowly through the site of investigation, since probes are generally sensitive to fast movements.

The RBS installation is assessed to be compliant without further investigation if the maximum measured TER is lower than 0,05⁵. If the measurement equipment does not have a shaped frequency response, the lowest electric field strength or power density exposure limit values in the frequency range used by the entire RBS installation shall be used to calculate TER .

⁵ In this case the 0,05 threshold is related to additional nearby sources.

Otherwise, a comprehensive *TER* measurement shall be performed according to 6.2.6.4.

6.2.6.4 Comprehensive *TER* measurement

The comprehensive *TER* measurement shall be performed at the location(s) of maximum *TER* found in the general *TER* evaluation. It is conducted in order to obtain a conservative estimate of the *TER* when the product is transmitting at maximum power.

The comprehensive measurement shall be performed using broadband or frequency selective measurement equipment that is in compliance with the requirements and the measurement procedures specified in B.3.1.2.

For comprehensive measurements, the extrapolation procedure as described in B.5 shall be applied and spatial averaging shall follow 6.4. Where the *ER* of the product obtained with comprehensive measurements is less than 0,05 no further evaluation is required, and the site is assessed to be compliant.

6.2.6.5 Exposure contribution of ambient sources

Ambient sources shall be identified according to the description in 7.2.

For evaluations where the extrapolation of the field strength to the maximum power has been obtained by means of broadband measurements, the contribution from ambient sources is implicitly evaluated. No additional measurements need to be performed.

For evaluations using a frequency selective device, exposure ratios of greater than or equal to 0,05 shall be considered as relevant sources. Sources with lower *ER* can be excluded.

If the operating bands of nearby ambient sources are known, the *ER* contribution of each source can be determined. This can be done using frequency selective equipment by integrating the field strength over the corresponding band. When this information is not directly available, it can be retrieved by inspection of the significant spectrum peaks measured by the frequency selective device.

For time variant signals, the field strength from relevant source contributions shall be scaled to maximum power (see B.5). If the extrapolation factors are unknown the power density for each of the relevant bands shall be measured. Such measurement should occur during high-traffic hours, using a max-hold trace for a time until the equipment reading stabilizes (typically 1 min or less). However, additional uncertainty associated with not actually scaling to maximum power should be appropriately accounted for in the uncertainty evaluation (see Clause 9).

6.2.7 Computations

Various computational methods can be used to evaluate the level of exposure within the DI (see B.4). An overview of the applicability of the methods is provided in Table 7.

The transmitted power of the RBS shall be conservatively assumed equal to the maximum power (theoretical or actual, see B.5). Ambient sources with a computed *ER* larger than 0,05 within the DI shall be included in the evaluation.

The effect of environmental reflectors and scatterers shall be considered where relevant, see B.3.1.2.6. In areas with environmental reflectors a modified free space approach may be applied. In this case the *ER* can be overestimated by using the *ER* estimated in free space multiplied by a factor. Alternatively, the effect of reflecting objects shall be included in the uncertainty budget.

Reflections can be modelled using calculation tools, such as Ray Tracing (see B.4.4.1). If not possible, a generic multiplicative factor of 2,56 (for power density) or 1,6 (for E-field) can be used as recommended in [15] for ground reflections. Other site-specific power density multiplication factors can be used where more detailed information is available. In general, an accurate estimation of these reflection factors requires information on site topography including material parameters of near-by structures, frequency, transmission bandwidth, and field polarization.

A reflecting structure may be excluded from the RF exposure computations if one or more of the following conditions apply:

- The reflecting structure is not within line of sight from both the point of investigation and the radio source.
- The geometry of the reflector, point of investigation and radio source is such that the reflected ray is directed away from the point of investigation.
- The maximum projected dimension of the reflecting structure in the direction of the point of investigation is less than $L_{\max}$ where

$$L_{\max} = \sqrt{\frac{d}{\lambda}}$$

where

d is the distance from the radio source to the structure;

λ is the wavelength of the considered radio source.

6.2.8 Uncertainty

Uncertainty analysis shall be performed according to Clause 9.

The target expanded uncertainty is 4 dB or below, which is considered industry best practice. The expanded uncertainty for the RF exposure evaluation used for the product installation compliance assessment shall not exceed 6 dB.

6.2.9 Reporting

Reporting shall be performed according to Clause 10. The RF exposure evaluation report used for product installation compliance shall contain at least the following.

- Description of the product:
 - name, reference (e.g. serial number), technologies;
 - maximum transmitted power for each transmit frequency band of the base station as installed;
 - antenna characteristics (gain, horizontal and vertical beamwidth) for each transmit frequency band, total *EIRP*, and a detailed description of the configuration of the base station in its operational environment, including antenna system (feeders, connectors, combiners, etc.). If the product installation compliance has been assessed using the simplified evaluation process as defined in 6.2.4, then all parameters used to define the installation class in Table 2 shall be included.
- Description of installation configuration for the product, including installation height, etc.
- Implementation of the simplified evaluation method (rationale, outcome) if applicable.
- If the simplified evaluation is not applicable, additional technical information required for repeatability and for documentation of the validity of the method are required. This shall include a description of the evaluation method and the exposure metrics (*TER*, *S*, *E* or *H*), the rationale for the choice (see 7.2), as well as:
 - description of the domain of investigation, relevant sources and scatters;

- spatial averaging method used;
- for measurements:
 - probe(s) and measurement instrument(s) used, including characteristics and calibration details,
 - testing conditions (temperature, etc.);
- for calculations:
 - name and version of the simulation tool (if applicable),
 - calculation and simulation parameters used;
- validity of measurement and/or calculation results.
- uncertainty analysis.
- Description of general public access restrictions, if any, and guidelines on how to comply with workers limits during installation, maintenance and repair of the product.

The documentation may cover several base stations with similar technical specifications and environmental conditions.

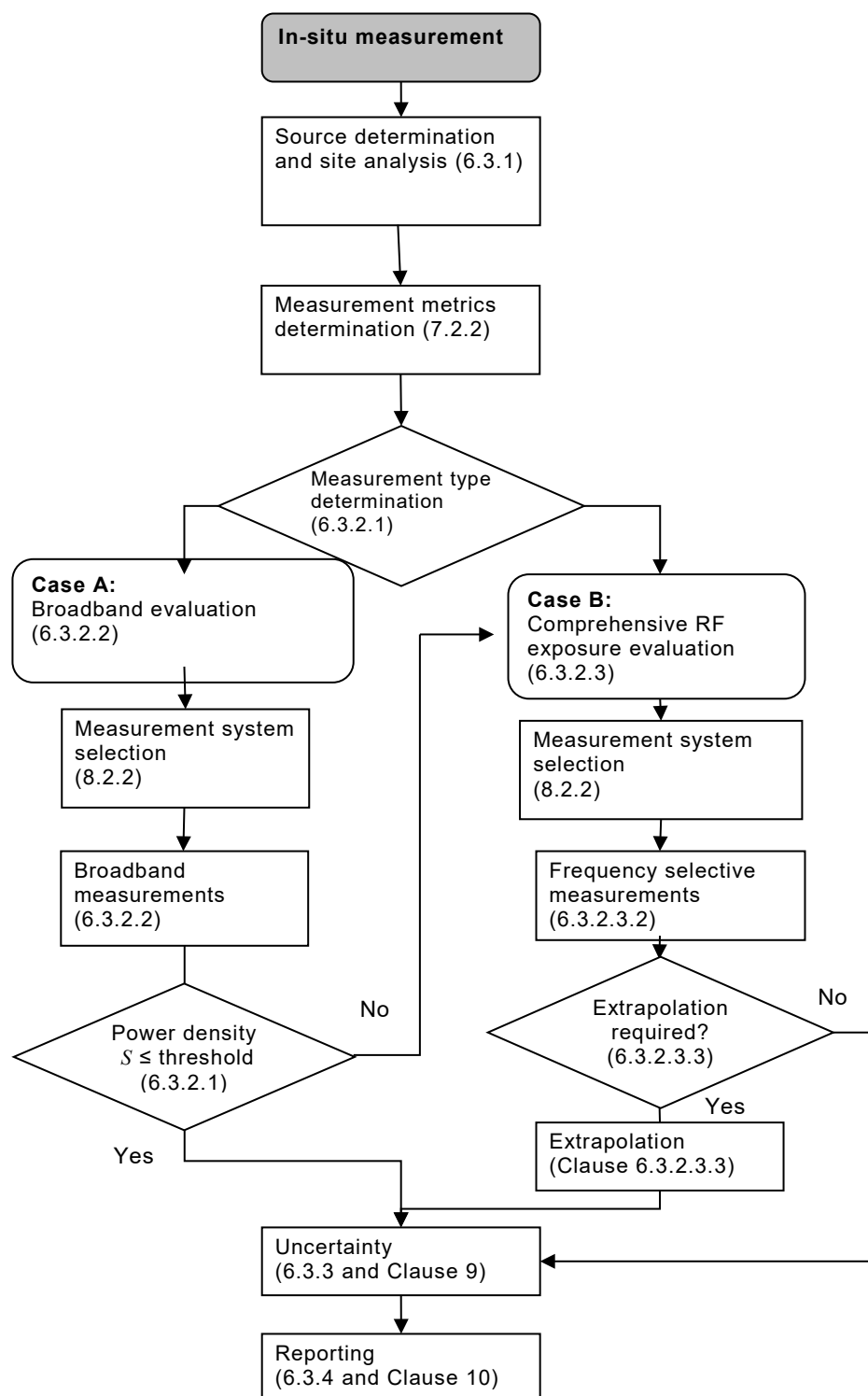
6.3 Evaluation processes for in-situ RF exposure assessment

6.3.1 General requirements, source determination and site analysis

The objectives of in-situ measurements are:

- to determine if the RF exposure levels are in compliance with applicable exposure limits and regulations, e.g. in the vicinity of an operating RBS installation, or
- to obtain the RF exposure data, typically required for communication purposes.

The procedure described in Figure 10 shall be used to evaluate in-situ RF exposure assessment based on measurement methods, uncertainty, and reporting specified in 6.3.2 to 6.3.4.



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Figure 10 – Alternative routes to evaluate in-situ RF exposure

The in-situ RF exposure evaluation or assessment shall be performed at one location or area, known as the measurement area.

The process shall start by identifying all relevant fixed and permanently emitting RF source installations in the surrounding area according to 7.2. The measurement system(s) and the post processing shall cover the RF emissions from the product and all relevant ambient sources between at least 100 kHz and 300 GHz as determined by the site analysis.

Then, the measurement metrics applicable on the measurement area shall be determined according to the distance from the source antenna, see 7.2.3).

NOTE In a complex field local minima and maxima occur within a relatively small area. Factors such as shadowing, reflection and diffraction, together with the radiation pattern characteristics of transmitting antennas, can be involved. The effects of fast fading, however, can be estimated and accounted for by spatial sampling and averaging (described in 6.4.).

6.3.2 Measurement procedures

6.3.2.1 Measurement type selection

The second step is to choose between two evaluation approaches, known as Case A and Case B as indicated in Figure 10. Case A provides a set of results covering all sources and frequencies at one measurement area. Case B provides separate sets of field values for each source, frequency or frequency sub-band present in the measurement area.

The choice of the measurement type depends on the objective of the in-situ evaluation.

- If the objective is to provide a global evaluation of RF exposure level from all sources together “as observed” (i.e. no extrapolation, no signal spectrum differentiation) then the evaluation shall start with Case A evaluation. However, if the power density assessment based on Case A is above applicable RF exposure limits (i.e. the threshold defined under Case A in Figure 10 is the applicable exposure limits) or if it is necessary or desired to investigate the contribution from each RF source, the Case A evaluation shall be complemented by a Case B evaluation.
- If the objective is to provide a detailed evaluation of RF exposure levels (i.e. combining the contributions of all RF sources, spectrum differentiation above a certain threshold), the evaluation shall start using Case A. If the power density level is above 10 mW/m² (i.e. threshold defined under Case A in Figure 10), the Case A evaluation shall be complemented by a Case B evaluation. However, if there are pre-existing national requirements, a different threshold between 5 mW/m² and 100 mW/m² may be used. Further, some national requirements may specify one method or another.
- If the objective is to provide a comprehensive evaluation of RF exposure, i.e. investigating every contribution from RF sources using a frequency selective analysis, then a Case B evaluation shall be conducted. It is recommended that a Case B evaluation is preceded by a Case A evaluation.

6.3.2.2 Case A (broadband evaluation)

Case A corresponds to an exposure evaluation on one measurement area using broadband equipment in compliance with 8.2.2 and B.3.1.2.3 and consistent with the purpose (6.1.1).

The measurement system(s) shall cover the frequency range of the RF emissions from the product and all relevant ambient sources between at least 100 kHz and 300 GHz as determined by the site analysis. Additional requirements are defined in B.3.1.2.2.

A Case A evaluation shall start by performing a slow scan over the measurement area at a height of 1,5 m above ground in order to find the location of the maximum exposure. At this location, if spatial averaging is applicable, measurements at different heights shall be performed in order to assess the spatial averaged value as described in 6.4.1. If time averaging is required, it shall be implemented as defined in 6.4.2.

Broadband measurements may be used to provide instantaneous environmental field-strength information or to indicate if it is necessary to perform a comprehensive exposure evaluation (Case B).

Broadband measurement in case of global or detailed RF exposure evaluation (Case A) shall not be used for extrapolation. Without the ability to discriminate frequency, such extrapolation could result in a large overestimation of the maximum exposure.

6.3.2.3 Case B (comprehensive exposure evaluation)

6.3.2.3.1 General

Case B corresponds to a comprehensive exposure evaluation with a frequency selective instrument, including identification of relevant sources, and extrapolation of exposure to maximum traffic load if required.

6.3.2.3.2 Measurement protocol

The operator shall use frequency selective measurement equipment as specified in 8.2.2 and B.3.1.2.4. Case B measurements shall be performed at a given location, e.g. the location of maximum exposure of a measurement area identified in Case A (see 6.3.2.2). The total exposure taking into account multiple frequencies shall be performed according to B.6.

The evaluation shall begin with a comprehensive frequency scan at the measurement location covering at least 100 kHz to 6 GHz, unless pre-evaluation of operating sources/ frequencies has been conducted and documented in the report. The scan results or pre-evaluation shall be used to identify for each technology the significant frequencies for which spatially averaged (see 6.4) or sweeping (see B.3.1.2.5.2) measurements, shall be conducted. In order to be able to accurately measure total exposure levels down to 1 % of the power density reference levels, sources shall be considered as significant when the exposure level is above 0,01 % (-40 dB) of the lowest power density reference level in the assessed frequency range. If no significant source is measured, the two highest sources shall be reported.

Frequency selective measurements shall be conducted at all points required for the implementation of spatial averaging or sweeping method. Depending on the objective of the in-situ evaluation or assessment, either the raw measurement results or the extrapolated measurement result, according to 6.3.2.3.3, shall be provided.

The total exposure shall be assessed using the summation formulas defined in B.6.

6.3.2.3.3 Extrapolation of the exposure at the network maximum traffic load

For the case where the aim is to evaluate the maximum exposure conditions taking into account traffic and transmitted power variations, then the evaluation result data shall be extrapolated. When extrapolation is performed it shall apply only to significant sources (see 6.3.2.3.2). The result shall be extrapolated from measurement of time independent channel(s) as defined in B.5 and Annex F.

6.3.3 Uncertainty

Uncertainty analysis shall be performed according to Clause 9.

The target expanded uncertainty is 4 dB or below, which is considered industry best practice. The expanded uncertainty for RF exposure evaluation used in in-situ RF exposure assessment shall not exceed 6 dB.

6.3.4 Reporting

Reporting shall be performed according to Clause 10. The in-situ RF exposure evaluation or assessment report shall contain at least:

- description of the measurement site, including the relevant RF sources and the points where measurements have been performed;
- environmental conditions, time and date, name of entity responsible for the measurement;
- measurement protocol used, including spatial averaging, time averaging, etc.;
- probe(s) and measurement instrument(s) used, including characteristics and calibration details and probe correction factors;