



**Determination of RF field strength,
power density and SAR in the
vicinity of radiocommunication base
stations for the purpose of evaluating
human exposure**

STANDARDS
Australia



AS IEC 62232:2018

This Australian Standard® was prepared by TE-007, Human Exposure to Electromagnetic Fields. It was approved on behalf of the Council of Standards Australia on 12 March 2018.

This Standard was published on 29 June 2018.

The following are represented on Committee TE-007:

Australian Centre for Radiofrequency Bioeffects Research
Australian Communications and Media Authority
Australian Industry Group
Australian Mobile Telecommunications Association
Australian Radiation Protection and Nuclear Safety Agency
Communications, Electrical and Plumbing Union (Electrical Trades Division)
Department of Defence (Australian Government)
Engineers Australia
National Measurement Institute
Telstra Corporation

This Standard was issued in draft form for comment as DR AS IEC 62232:2017.

Keeping Standards up-to-date

Ensure you have the latest versions of our publications and keep up-to-date about Amendments, Rulings, Withdrawals, and new projects by visiting:

www.standards.org.au

www.saiglobal.com (sales and distribution)

ISBN 978 1 76072 037 7



**Determination of RF field strength,
power density and SAR in the
vicinity of radiocommunication base
stations for the purpose of evaluating
human exposure**

First published as AS IEC 62232:2018.

COPYRIGHT

© IEC 2018 — All rights reserved
© Standards Australia Limited 2018

All rights are reserved. No part of this work may be reproduced or copied in any form or by any means, electronic or mechanical, including photocopying, without the written permission of the publisher, unless otherwise permitted under the Copyright Act 1968 (Cth).

Published by SAI Global Pty Limited under licence from Standards Australia Limited, GPO Box 476, Sydney, NSW 2001, Australia.

Preface

This Standard was prepared by the Australian members of the Joint Standards Australia/Standards New Zealand Committee TE-007, Human Exposure to Electromagnetic Fields.

The objective of this Standard is to provide methods for the determination of radio-frequency (RF) field strength, power density and specific absorption rate (SAR) in the vicinity of radiocommunication base stations (RBS) for the purpose of evaluating human exposure.

After consultation with stakeholders in both countries, Standards Australia and Standards New Zealand decided to develop this Standard as an Australian Standard rather than an Australian/New Zealand Standard.

This Standard is identical with, and has been reproduced from, IEC 62232:2017, *Determination of Rf field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure*.

As this document has been reproduced from an International Standard, a full point substitutes for a comma when referring to a decimal marker.

Australian or Australian/New Zealand Standards that are identical adoptions of international normative references may be used interchangeably. Refer to the online catalogue for information on specific Standards.

The terms 'normative' and 'informative' are used in Standards to define the application of the appendices or annexes to which they apply. A 'normative' appendix or annex is an integral part of a Standard, whereas an 'informative' appendix or annex is only for information and guidance.

This Standard is published with an accompanying product which consists of a zip file which contains Excel files. These files are referenced in the text. The original IEC text refers to the Excel files being embedded in the text, however they are not embedded in the pdf of this adoption. They may be obtained on purchase of the Standard, in the following manner:

- (1) USB Flash drive containing a Zip file with the drawings files, for hard copy purchasers.
- (2) Zip file with the drawings files, for PDF purchasers downloaded from the SAI Global Infostore.

These files are intended to be used as a complement and do not form an integral part of the standard.

The files in the accompanying products shall only be used, reproduced or modified by an authorised user in a way that meets the requirements of this Standard. They shall not be used for any other purposes.

CONTENTS

FOREWORD.....	12
INTRODUCTION.....	14
1 Scope.....	15
2 Normative references	15
3 Terms and definitions	16
4 Symbols and abbreviated terms.....	22
4.1 Physical quantities	22
4.2 Constants	23
4.3 Abbreviated terms.....	22
5 Quick start guide and how to use this document	24
5.1 Overview.....	24
5.2 Quick start guide.....	24
5.3 How to use this document.....	26
5.4 Worked case studies.....	27
6 Evaluation processes for product compliance, product installation compliance and in-situ RF exposure assessments	27
6.1 Evaluation process for product compliance	27
6.1.1 General	27
6.1.2 Establishing compliance boundaries	27
6.1.3 Iso-surface compliance boundary definition	28
6.1.4 Simple compliance boundaries	28
6.1.5 Methods for establishing the compliance boundary	30
6.1.6 Uncertainty	32
6.1.7 Reporting.....	32
6.2 Evaluation process used for product installation compliance	33
6.2.1 General	33
6.2.2 General evaluation procedure for product installations.....	33
6.2.3 Product installation data collection.....	34
6.2.4 Simplified product installation evaluation process	35
6.2.5 Assessment criteria selection	37
6.2.6 Measurements.....	39
6.2.7 Computations	40
6.2.8 Uncertainty	41
6.2.9 Reporting.....	41
6.3 Evaluation processes for in-situ RF exposure assessment	42
6.3.1 General requirements, source determination and site analysis.....	42
6.3.2 Measurement procedures	44
6.3.3 Uncertainty	45
6.3.4 Reporting.....	45
6.4 Averaging procedures	46
6.4.1 Spatial averaging.....	46
6.4.2 Time averaging.....	46
7 Determining the evaluation method.....	46
7.1 Overview.....	46
7.2 Process to determine the evaluation method.....	46
7.2.1 General	46

7.2.2	Establishing the evaluation points in relation to the source-environment plane	47
7.2.3	Exposure metric selection	49
8	Evaluation methods	49
8.1	Overview	49
8.2	Measurement methods	50
8.2.1	General	50
8.2.2	RF field strength measurements	50
8.2.3	<i>SAR</i> measurements	51
8.3	Computation methods	52
9	Uncertainty	53
10	Reporting	54
10.1	General requirements	54
10.2	Report format	54
10.3	Opinions and interpretations	55
Annex A (informative) Source environment plane and guidance on the evaluation method selection		56
A.1	Guidance on the source-environment plane	56
A.1.1	General	56
A.1.2	Source-environment plane example	56
A.1.3	Source regions	57
A.2	Select between computation or measurement approaches	63
A.3	Select measurement method	64
A.3.1	Selection stages	64
A.3.2	Selecting between field strength and <i>SAR</i> measurement approaches	64
A.3.3	Selecting between broadband and frequency-selective measurement	65
A.3.4	Selecting RF field strength measurement procedures	66
A.4	Select computation method	66
A.5	Additional consideration	68
A.5.1	Simplicity	68
A.5.2	Evaluation method ranking	68
A.5.3	Applying multiple methods for RF exposure evaluation	68
Annex B (normative) Evaluation methods		69
B.1	Overview	69
B.2	Evaluation parameters	69
B.2.1	Overview	69
B.2.2	Coordinate systems	69
B.2.3	Reference points	70
B.2.4	Variables	70
B.3	Measurement methods	73
B.3.1	RF field strength measurements	73
B.3.2	<i>SAR</i> measurements	104
B.4	Computation methods	114
B.4.1	Overview and general requirements	114
B.4.2	Formulas	115
B.4.3	Basic algorithms	123
B.4.4	Advanced computation methods	129
B.5	Extrapolation from the evaluated <i>SAR</i> / RF field strength to the required assessment condition	150

B.5.1	Extrapolation method	150
B.5.2	Extrapolation to maximum RF field strength using broadband measurements	151
B.5.3	Extrapolation to maximum RF field strength for frequency and code selective measurements	151
B.5.4	Influence of traffic in real operating network	152
B.6	Summation of multiple RF fields	152
B.6.1	Applicability	152
B.6.2	Uncorrelated fields	153
B.6.3	Correlated fields	153
B.6.4	Ambient fields	153
Annex C	(informative) Rationale supporting simplified product installation criteria	154
C.1	General	154
C.2	Class E2	154
C.3	Class E10	155
C.4	Class E100	155
C.5	Class E+	157
Annex D	(informative) Guidance on comparing evaluated parameter with a limit value	159
D.1	Overview	159
D.2	Information required to compare evaluated value against limit value	159
D.3	Performing a limit comparison at a given confidence level	159
D.4	Performing a limit comparison using a process based assessment scheme	160
Annex E	(informative) Uncertainty	161
E.1	Background	161
E.2	Requirement to estimate uncertainty	161
E.3	How to estimate uncertainty	162
E.4	Guidance on uncertainty and assessment schemes	162
E.4.1	General	162
E.4.2	Overview of assessment schemes	162
E.4.3	Examples of assessment schemes	163
E.4.4	Assessment schemes and compliance probabilities	166
E.5	Guidance on uncertainty	168
E.5.1	Overview	168
E.5.2	Measurement uncertainty and confidence levels	169
E.6	Applying uncertainty for compliance assessments	170
E.7	Example influence quantities for field measurements	170
E.7.1	General	170
E.7.2	Calibration uncertainty of measurement antenna or field probe	171
E.7.3	Frequency response of the measurement antenna or field probe	171
E.7.4	Isotropy of the measurement antenna or field probe	173
E.7.5	Frequency response of the spectrum analyser	173
E.7.6	Temperature response of a broadband field probe	173
E.7.7	Linearity deviation of a broadband field probe	173
E.7.8	Mismatch uncertainty	173
E.7.9	Deviation of the experimental source from numerical source	174
E.7.10	Meter fluctuation uncertainty for time varying signals	174
E.7.11	Uncertainty due to power variation in the RF source	174
E.7.12	Uncertainty due to field gradients	174

E.7.13	Mutual coupling between measurement antenna or isotropic probe and object	176
E.7.14	Uncertainty due to field scattering from the surveyor's body	177
E.7.15	Measurement device	178
E.7.16	Fields out of measurement range	178
E.7.17	Noise	179
E.7.18	Integration time	179
E.7.19	Power chain	179
E.7.20	Positioning system	179
E.7.21	Matching between probe and the EUT	179
E.7.22	Drifts in output power of the EUT, probe, temperature, and humidity	179
E.7.23	Perturbation by the environment	179
E.8	Example influence quantities for RF field strength computations by ray tracing or full wave methods	180
E.8.1	General	180
E.8.2	System	180
E.8.3	Technique uncertainties	181
E.8.4	Environmental uncertainties	181
E.9	Influence quantities for <i>SAR</i> measurements	182
E.9.1	General	182
E.9.2	Post-processing	182
E.9.3	Device holder	182
E.9.4	Test sample positioning	183
E.9.5	Phantom shell uncertainty	184
E.9.6	<i>SAR</i> correction / target liquid permittivity and conductivity	184
E.9.7	Liquid permittivity and conductivity measurements	184
E.9.8	Liquid temperature	185
E.10	Influence quantities for <i>SAR</i> calculations	185
E.11	Spatial averaging	185
E.11.1	General	185
E.11.2	Small-scale fading variations	186
E.11.3	Error on the estimation of local average power density	186
E.11.4	Error on the estimation of local average power density	187
E.11.5	Characterization of environment statistical properties	187
E.11.6	Characterization of different averaging schemes	188
E.12	Influence of human body on probe measurements of the electrical field strength	192
E.12.1	Simulations of the influence of human body on probe measurements based on the Method of Moments (Surface Equivalence Principle)	192
E.12.2	Comparison with measurements	194
E.12.3	Conclusions	194
Annex F (informative)	Technology-specific guidance	195
F.1	Overview to guidance on specific technologies	195
F.2	Summary of technology-specific information	195
F.3	Guidance on spectrum analyser settings	199
F.3.1	Overview of spectrum analyser settings	199
F.3.2	Detection algorithms	199
F.3.3	Resolution bandwidth and channel power processing	200
F.3.4	Integration per service	202
F.4	Constant power components	203

F.4.1	TDMA/FDMA technology.....	203
F.4.2	WCDMA/UMTS technology.....	203
F.4.3	OFDM technology.....	204
F.5	WCDMA measurement and calibration using a code domain analyser.....	204
F.5.1	WCDMA measurements – General.....	204
F.5.2	Requirements for the code domain analyser.....	204
F.5.3	Calibration.....	205
F.6	Wi-Fi measurements.....	207
F.6.1	General.....	207
F.6.2	Integration time for reproducible measurements.....	207
F.6.3	Channel occupation.....	208
F.6.4	Some considerations.....	208
F.6.5	Scalability by channel occupation.....	209
F.6.6	Influence of the application layers.....	209
F.7	LTE measurements for Frequency Division Duplexing (FDD).....	209
F.7.1	Overview.....	209
F.7.2	Maximum LTE exposure evaluation.....	210
F.7.3	Instantaneous LTE exposure evaluation.....	213
F.7.4	MIMO multiplexing of LTE base station.....	213
F.8	LTE measurements for Time Division Duplexing (TDD).....	214
F.8.1	General.....	214
F.8.2	Definitions and transmission modes.....	214
F.8.3	TDD frame structure.....	215
F.8.4	Maximum LTE exposure evaluation.....	217
F.9	Establishing compliance boundaries using numerical simulations of MIMO array antennas emitting correlated wave-forms.....	220
F.9.1	General.....	220
F.9.2	Field combining near radio base stations for correlated exposure with the purpose of establishing compliance boundaries.....	221
F.9.3	Numerical simulation of MIMO array antennas with densely packed columns.....	222
F.9.4	Numerical simulations of large MIMO array antennas.....	222
F.10	Smart antennas.....	223
F.10.1	Overview.....	223
F.10.2	Deterministic conservative approach.....	223
F.10.3	Statistical conservative approach.....	223
F.10.4	Example approaches.....	224
F.10.5	Smart antenna (TD-LTE).....	233
F.11	Establishing compliance boundary for systems using dish antennas.....	233
F.11.1	General.....	233
F.11.2	Overview.....	234
F.11.3	Compliance boundary of a dish antenna.....	234
	Bibliography.....	236
	Figure 1 – Quick start guide to the evaluation process.....	25
	Figure 2 – Example of complex compliance boundary.....	28
	Figure 3 – Example of circular cylindrical compliance boundaries.....	28
	Figure 4 – Example of box shaped compliance boundary.....	29
	Figure 5 – Example of truncated box shaped compliance boundary.....	29

Figure 6 – Example of dish antenna compliance boundary (from [11]).....	30
Figure 7 – Example illustrating the linear scaling procedure.....	31
Figure 8 – Flowchart describing the product installation evaluation process.....	34
Figure 9 – Square-shaped assessment domain boundary (ADB) with size D_{ad}	39
Figure 10 – Alternative routes to evaluate in-situ RF exposure.....	43
Figure 11 – Source-environment plane concept.....	48
Figure 12 – Flow chart of the measurement methods.....	50
Figure 13 – Flow chart of the relevant computation methods.....	52
Figure A.1 – Example source-environment plane regions near a radio base station antenna on a tower which has a narrow vertical (elevation plane) beamwidth (not to scale).....	56
Figure A.2 – Example source-environment plane regions near a roof-top antenna which has a narrow vertical (elevation plane) beamwidth (not to scale).....	57
Figure A.3 – Geometry of an antenna with largest linear dimension L_{eff} and largest end dimension L_{end}	58
Figure A.4 – Maximum path difference for an antenna with largest linear dimension L	62
Figure B.1 – Cylindrical, cartesian and spherical coordinates relative to the RBS antenna.....	70
Figure B.2 – Evaluation locations.....	81
Figure B.3 – Relationship of separation of remote radio source and evaluation area to separation of evaluation points.....	82
Figure B.4 – Outline of the surface scanning methodology.....	84
Figure B.5 – Block diagram of the near-field antenna measurement system.....	85
Figure B.6 – Minimum radius constraint where a denotes the minimum radius of a sphere, centred at the reference point, that will encompass the EUT.....	86
Figure B.7 – Maximum angular sampling spacing constraint.....	86
Figure B.8 – Outline of the volume/surface scanning methodology.....	90
Figure B.9 – Block diagram of typical near-field EUT measurement system.....	91
Figure B.10 – Spatial averaging schemes relative to foot support level and in the vertical plane oriented to offer maximum area in the direction of the source being evaluated.....	97
Figure B.11 – Spatial averaging relative to spatial-peak field strength point height.....	97
Figure B.12 – Positioning of the EUT relative to the relevant phantom.....	105
Figure B.13 – Phantom liquid volume and measurement volume used for whole-body SAR measurements with the box-shaped phantoms.....	111
Figure B.14 – Reflection due to the presence of a ground plane.....	116
Figure B.15 – Enclosed cylinder around collinear arrays, with and without electrical dipoles.....	116
Figure B.16 – Leaky feeder geometry.....	118
Figure B.17 – Directions for which SAR estimation expressions are given.....	119
Figure B.18 – Reference frame employed for cylindrical formulas for field strength computation at a point P (left), and on a line perpendicular to boresight (right).....	124
Figure B.19 – Views illustrating the three valid zones for field strength computation around an antenna.....	125
Figure B.20 – Cylindrical formulas reference results.....	128
Figure B.21 – Spherical formulas reference results.....	129
Figure B.22 – Synthetic model and ray tracing algorithms geometry and parameters.....	131

Figure B.23 – Line 4 far-field positions for synthetic model and ray tracing validation example	134
Figure B.24 – Antenna parameters for synthetic model and ray tracing algorithms validation example	135
Figure B.25 – Generic 900 MHz RBS antenna with nine dipole radiators	142
Figure B.26 – Line 1, 2 and 3 near-field positions for full wave and ray tracing validation	142
Figure B.27 – Generic 1 800 MHz RBS antenna with five slot radiators	143
Figure B.28 – RBS antenna placed in front of a multi-layered lossy cylinder	149
Figure B.29 – Time variation over 24 h of the exposure induced by GSM 1800 MHz (left) and FM (right) both normalized to mean	152
Figure C.1 – Measured ER as a function of distance for a low power BS ($G = 5$ dBi, $f = 2\,100$ MHz) transmitting with an $EIRP$ of 2 W (class E2) and 10 W (class E10)	154
Figure C.2 – Minimum installation height as a function of transmitting power corresponding to class E10	155
Figure C.3 – Compliance distance in the main lobe as a function of $EIRP$ established according to the far-field formula corresponding to class E100	156
Figure C.4 – Minimum installation height as a function of transmitting power corresponding to class E100	156
Figure C.5 – Averaged power density at ground level for various installation configurations of equipment with 100 W $EIRP$ (class E100)	157
Figure C.6 – Compliance distance in the main lobe as a function of $EIRP$ established according to the far-field formula corresponding to class E+	158
Figure C.7 – Minimum installation height as a function of transmitting power corresponding to class E+	158
Figure E.1 – Examples of general assessment schemes	164
Figure E.2 – Target uncertainty scheme overview	165
Figure E.3 – Probability of the true value being above (respectively below) the evaluated value depending on the confidence level assuming a normal distribution	169
Figure E.4 – Plot of the calibration factors for E (not E^2) provided from an example calibration report for an electric field probe	172
Figure E.5 – Computational model used for the variational analysis of reflected RF fields from the front of a surveyor	177
Figure E.6 – Positioning device and different positioning errors	183
Figure E.7 – Physical model of Rayleigh (a) and Rice (b) small-scale fading variations	185
Figure E.8 – Example of E field strength variations in line of sight of an antenna operating at 2,2 GHz	186
Figure E.9 – Error at 95% on average power estimation	187
Figure E.10 – 343 measurement positions building a cube (centre) and different templates consisting of a different number of positions	188
Figure E.11 – Moving a template (Line 3) through the CUBE	189
Figure E.12 – Standard deviations for GSM 900, DCS 1800 and UMTS	191
Figure E.13 – Simulation arrangement	193
Figure E.14 – Body influence	193
Figure E.15 – Simulation arrangement	194
Figure F.1 – Spectral occupancy for GMSK	200
Figure F.2 – Spectral occupancy for CDMA	201
Figure F.3 – Channel allocation for a WCDMA signal	204

Figure F.4 – Example of Wi-Fi frames	207
Figure F.5 – Channel occupation versus the integration time for IEEE 802.11b standard	208
Figure F.6 – Channel occupation versus nominal throughput rate for IEEE 802.11b/g standards.....	208
Figure F.7 – Wi-Fi spectrum trace snapshot.....	209
Figure F.8 – Frame structure of transmission signal for LTE downlink	210
Figure F.9 – Examples of received waves from LTE downlink signals using a spectrum analyser using zero span mode.....	213
Figure F.10 – Frame structure type 2 (for 5 ms switch-point periodicity).....	216
Figure F.11 – Frame structure of transmission signal for TDD LTE	216
Figure F.12 – PBCH measurement example.....	218
Figure F.13 – PBCH measurement example spectrum analyser using zero span mode	220
Figure F.14 – MIMO array antenna with densely packed columns	221
Figure F.15 – Plan view representation of statistical conservative model	224
Figure F.16 – Binomial cumulative probability function for $N = 24$, $PR = 0,125$	232
Figure F.17 – Binomial cumulative probability function for $N = 18$, $PR = 2/7$	233
Figure F.18 – Flowchart for the assessment of EMF compliance boundary in the line of sight of dish antennas (from [11]).....	235
Table 1 – Quick start guide evaluation steps	26
Table 2 – Example of product installation classes where a simplified evaluation process is applicable (based on ICNIRP general public limits [13])	36
Table 3 – Exposure metrics validity for evaluation points in each source region	49
Table 4 – Requirements for RF field strength measurements	51
Table 5 – Whole-body <i>SAR</i> exclusions based on RF power levels.....	51
Table 6 – Requirements for <i>SAR</i> measurements.....	51
Table 7 – Applicability of computation methods for source-environment regions of Figure 10	53
Table 8 – Requirements for computation methods.....	53
Table A.1 – Definition of source regions.....	59
Table A.2 – Default source region boundaries.....	59
Table A.3 – Source region boundaries for antennas with maximum dimension less than $2,5 \lambda$	60
Table A.4 – Source region boundaries for linear/planar antenna arrays with a maximum dimension greater than or equal to $2,5 \lambda$	60
Table A.5 – Source region boundaries for equiphase radiation aperture (e.g. dish) antennas with maximum reflector dimension much greater than a wavelength	61
Table A.6 – Source region boundaries for leaky feeders	61
Table A.7 – Far-field distance r measured in metres as a function of angle β	63
Table A.8 – Guidance on selecting between computation and measurement approaches.....	64
Table A.9 – Guidance on selecting between broadband and frequency-selective measurement.....	65
Table A.10 – Guidance on selecting RF field strength measurement procedures.....	66
Table A.11 – Guidance on selecting computation methods.....	67

Table A.12 – Guidance on specific evaluation method ranking	68
Table B.1 – Dimension variables	70
Table B.2 – RF power variables	71
Table B.3 – Antenna variables	72
Table B.4 – Exposure metric variables	73
Table B.5 – Broadband measurement system requirements	75
Table B.6 – Frequency-selective measurement system requirements	76
Table B.7 – Sample template for estimating the expanded uncertainty of an in-situ RF field strength measurement that used a frequency-selective instrument	100
Table B.8 – Sample template for estimating the expanded uncertainty of an in-situ RF field strength measurement that used a broadband instrument	101
Table B.9 – Sample template for estimating the expanded uncertainty of a laboratory- based RF field strength measurement using the surface scanning method	102
Table B.10 – Sample template for estimating the expanded uncertainty of a laboratory- based RF field strength measurement using the volume scanning method	103
Table B.11 – Numerical reference <i>SAR</i> values for reference dipoles and flat phantom – All values are normalized to a forward power of 1 W	108
Table B.12 – Phantom liquid volume and measurement volume used for whole-body <i>SAR</i> measurements [35], [29]	111
Table B.13 – Correction factor to compensate for a possible bias in the obtained general public whole-body <i>SAR</i> when assessed using the large box-shaped phantom for child exposure configurations [36]	111
Table B.14 – Measurement uncertainty evaluation template for EUT whole-body <i>SAR</i> test ..	112
Table B.15 – Measurement uncertainty evaluation template for whole-body <i>SAR</i> system validation	113
Table B.16 – Applicability of <i>SAR</i> estimation formulas	120
Table B.17 – Definition of $C(f)$	121
Table B.18 – Input parameters for <i>SAR</i> estimation formulas validation	123
Table B.19 – SAR_{10g} and SAR_{wb} estimation formula reference results for Table B.18 parameters and a body mass of 46 kg	123
Table B.20 – Definition of boundaries for selecting the zone of computation	126
Table B.21 – Input parameters for cylinder and spherical formulas validation	128
Table B.22 – Sample template for estimating the expanded uncertainty of a synthetic model and ray tracing RF field strength computation	133
Table B.23 – Synthetic model and ray tracing power density reference results	136
Table B.24 – Sample template for estimating the expanded uncertainty of a full wave RF field strength computation	140
Table B.25 – Validation 1 full wave field reference results	143
Table B.26 – Validation 2 full wave field reference results	144
Table B.27 – Sample template for estimating the expanded uncertainty of a full wave <i>SAR</i> computation	147
Table B.28 – Validation reference <i>SAR</i> results for computation method	149
Table E.1 – Determining target uncertainty	165
Table E.2 – Monte Carlo simulation of 10 000 trials, both surveyor and auditor using best estimate	167
Table E.3 – Monte Carlo simulation of 10 000 trials, both surveyor and auditor using target uncertainty of 4 dB	167

Table E.4 – Monte Carlo simulation of 10 000 trials surveyor uses upper 95 % CI vs. auditor uses lower 95 % CI	168
Table E.5 – Guidance on minimum separation distances for some dipole lengths to ensure that the uncertainty does not exceed 5 % or 10 % in a measurement of E	175
Table E.6 – Guidance on minimum separation distances for some loop diameters to ensure that the uncertainty does not exceed 5 % or 10 % in a measurement of H	176
Table E.7 – Example minimum separation conditions for selected dipole lengths for 10 % uncertainty in E	176
Table E.8 – Standard estimates of dB variation for the perturbations in front of a surveyor due to body reflected fields as described in Figure E.5	178
Table E.9 – Standard uncertainty (u) estimates for E and H due to body reflections from the surveyor for common radio services derived from estimates provided in Table E.8.....	178
Table E.10 – Maximum sensitivity coefficients for liquid permittivity and conductivity over the frequency range 300 MHz to 6 GHz.....	185
Table E.11 – Uncertainty at 95 % for different fading models	188
Table E.12 – Correlation coefficients for GSM 900 and DCS 1800	190
Table E.13 – Variations of the standard deviations for the GSM 900, DCS 1800 and UMTS frequency band	191
Table E.14 – Examples of total uncertainty calculation.....	192
Table E.15 – Maximum simulated error due to the influence of a human body on the measurement values of an omni-directional probe	194
Table E.16 – Measured influence of a human body on omni-directional probe measurements	194
Table F.1 – Technology specific information	196
Table F.2 – Example of spectrum analyser settings for an integration per service	202
Table F.3 – Example constant power components for specific TDMA/FDMA technologies	203
Table F.4 – WCDMA decoder requirements	205
Table F.5 – Signal configurations.....	205
Table F.6 – WCDMA generator setting for power linearity	206
Table F.7 – WCDMA generator setting for decoder calibration	206
Table F.8 – WCDMA generator setting for reflection coefficient measurement	207
Table F.9 – Theoretical extrapolation factor, N_{RS} , based on frame structure given in 3GPP TS 36.104 [10].....	212
Table F.10 – Configuration of special subframe (lengths of DwPTS/GP/UpPTS)	217
Table F.11 – Uplink-downlink configurations	217

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**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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)*