

© Copyright SEK Svensk Elstandard. Reproduction in any form without permission is prohibited.

Metod för mätning av specifik absorptionshastighet (SAR) avseende exponering för radiofrekventa elektromagnetiska fält från handhållen och kroppsburen trådlös kommunikationsutrustning – Del 1528: Kroppsmodeller, instrumentering och metoder (4 MHz till 10 GHz)

*Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-worn wireless communication devices –
Part 1528: Human models, instrumentation and procedures (Frequency range of 4 MHz to 10 GHz)*

Som svensk standard gäller europastandarden EN IEC/IEEE 62209-1528:2021. Den svenska standarden innehåller den officiella engelska språkversionen av EN IEC/IEEE 62209-1528:2021.

Nationellt förord

Europastandarden EN IEC/IEEE 62209-1528:2021

består av:

- **europastandardens ikraftsättningsdokument**, utarbetat inom CENELEC
- **IEC/IEEE 62209-1528, First edition, 2020 - Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-worn wireless communication devices - Part 1528: Human models, instrumentation and procedures (Frequency range of 4 MHz to 10 GHz)**

utarbetad inom International Electrotechnical Commission, IEC.

Tidigare fastställd svensk standard SS-EN 62209-1, utgåva 2, 2017, SS-EN 62209-2, utgåva 1, 2010 med ändringarna SS-EN 62209-2/A1:2019, gäller ej fr o m 2024-11-19.

Standarder underlättar utvecklingen och höjer elsäkerheten

Det finns många fördelar med att ha gemensamma tekniska regler för bl a mätning, säkerhet och provning och för utförande, skötsel och dokumentation av elprodukter och elanläggningar.

Genom att utforma sådana standarder blir säkerhetsfordringar tydliga och utvecklingskostnaderna rimliga samtidigt som marknadens acceptans för produkten eller tjänsten ökar.

Många standarder inom elområdet beskriver tekniska lösningar och metoder som åstadkommer den elsäkerhet som föreskrivs av svenska myndigheter och av EU.

SEK är Sveriges röst i standardiseringsarbetet inom elområdet

SEK Svensk Elstandard svarar för standardiseringen inom elområdet i Sverige och samordnar svensk medverkan i internationell och europeisk standardisering. SEK är en ideell organisation med frivilligt deltagande från svenska myndigheter, företag och organisationer som vill medverka till och påverka utformningen av tekniska regler inom elektrotekniken.

SEK samordnar svenska intressenters medverkan i SEKs tekniska kommittéer och stödjer svenska experters medverkan i internationella och europeiska projekt.

Stora delar av arbetet sker internationellt

Utformningen av standarder sker i allt väsentligt i internationellt och europeiskt samarbete. SEK är svensk nationalkommitté av International Electrotechnical Commission (IEC) och Comité Européen de Normalisation Electrotechnique (CENELEC).

Standardiseringsarbetet inom SEK är organiserat i referensgrupper bestående av ett antal tekniska kommittéer som speglar hur arbetet inom IEC och CENELEC är organiserat.

Arbetet i de tekniska kommittéerna är öppet för alla svenska organisationer, företag, institutioner, myndigheter och statliga verk. Den årliga avgiften för deltagandet och intäkter från försäljning finansierar SEKs standardiseringsverksamhet och medlemsavgift till IEC och CENELEC.

Var med och påverka!

Den som deltar i SEKs tekniska kommittéarbete har möjlighet att påverka framtida standarder och får tidig tillgång till information och dokumentation om utvecklingen inom sitt teknikområde. Arbetet och kontakterna med kollegor, kunder och konkurrenter kan gynnsamt påverka enskilda företags affärsutveckling och bidrar till deltagarnas egen kompetensutveckling.

Du som vill dra nytta av dessa möjligheter är välkommen att kontakta SEKs kansli för mer information.

SEK Svensk Elstandard

Box 1284
164 29 Kista
Tel 08-444 14 00
www.elstandard.se

English Version

Measurement procedure for the assessment of specific
absorption rate of human exposure to radio frequency fields from
hand-held and body-mounted wireless communication devices -
Part 1528: Human models, instrumentation, and procedures
(Frequency range of 4 MHz to 10 GHz)
(IEC/IEEE 62209-1528:2020)

Procédure de mesure pour l'évaluation du débit
d'absorption spécifique de l'exposition humaine aux champs
radiofréquence produits par les dispositifs de
communications sans fil tenus à la main ou portés près du
corps - Partie 1528: Modèles humain, instrumentation et
procédures (Plage de fréquences comprise entre 4 MHz et
10 GHz)
(IEC/IEEE 62209-1528:2020)

Messverfahren für die Beurteilung der spezifischen
Absorptionsrate bei der Exposition von Personen
gegenüber hochfrequenten Feldern von handgehaltenen
und am Körper getragenen schnurlosen
Kommunikationsgeräten - Teil 1528: Körpermodelle,
Messgeräte und -verfahren (Frequenzbereich von 4 MHz
bis 10 GHz)
(IEC/IEEE 62209-1528:2020)

This European Standard was approved by CENELEC on 2021-06-03. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.



European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

This document (EN IEC/IEEE 62209-1528:2021) consists of the text of IEC/IEEE 62209-1528:2020 prepared by IEC/TC 106 "Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure".

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2022-05-19
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2024-11-19

This document supersedes EN 62209-1:2016 and EN 62209-2:2010 and all of their amendments and corrigenda (if any).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

Any feedback and questions on this document should be directed to the users' national committee. A complete listing of these bodies can be found on the CENELEC website.

Endorsement notice

The text of the International Standard IEC/IEEE 62209-1528:2020 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 17025:2017	NOTE	Harmonized as EN ISO/IEC 17025:2017 (not modified)
IEC 62479:2010	NOTE	Harmonized as EN 62479:2010 (modified)
IEC 62311:2019	NOTE	Harmonized as EN IEC 62311:2020 (not modified)
IEC 60154-2	NOTE	Harmonized as EN 60154-2
ISO 10012:2003	NOTE	Harmonized as EN ISO 10012:2003 (not modified)
ISO/IEC 17043:2010	NOTE	Harmonized as EN ISO/IEC 17043:2010 (not modified)

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 62209-3	2019	Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - Part 3: Vector measurement-based systems (Frequency range of 600 MHz to 6 GHz)	EN IEC 62209-3	2019
ISO/IEC Guide 98-3	2008	Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)	-	-



IEEE

IEC/IEEE 62209-1528

Edition 1.0 2020-10

INTERNATIONAL STANDARD



**Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices –
Part 1528: Human models, instrumentation, and procedures
(Frequency range of 4 MHz to 10 GHz)**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 17.220.20

ISBN 978-2-8322-8533-6

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	14
INTRODUCTION.....	17
1 Scope.....	18
2 Normative references	18
3 Terms and definitions	18
4 Symbols and abbreviated terms.....	26
4.1 Physical quantities	26
4.2 Constants	26
4.3 Abbreviated terms.....	27
5 Quick start guide and evaluation plan checklist.....	28
6 Measurement system specifications.....	30
6.1 General requirements for full SAR testing	30
6.2 Phantom specifications	31
6.2.1 General	31
6.2.2 Basic phantom parameters	31
6.2.3 Head phantom	33
6.2.4 Flat phantom	34
6.2.5 Device-specific phantoms	35
6.3 Influence of hand on SAR in head.....	35
6.4 Scanning system requirements	36
6.5 Device holder specifications.....	36
6.6 Characteristics of the readout electronics	37
7 Protocol for SAR assessment	37
7.1 General.....	37
7.2 Measurement preparation	37
7.2.1 Preparation of tissue-equivalent medium and system check.....	37
7.2.2 Preparation of the wireless communication DUT	38
7.2.3 DUT operating mode requirements	38
7.2.4 Positioning of the DUT relative to the phantom	40
7.2.5 Antenna configurations	57
7.2.6 Options and accessories.....	57
7.2.7 DUTs with alternative form factor.....	57
7.2.8 Test frequencies for DUTs	58
7.3 Tests to be performed for DUTs	58
7.3.1 General	58
7.3.2 Basic approach for DUT testing	59
7.4 Measurement procedure	60
7.4.1 General	60
7.4.2 Full SAR testing procedure	60
7.4.3 Drift	64
7.4.4 SAR measurements of DUTs with multiple antennas or multiple transmitters	66
7.5 Post-processing of SAR measurement data	72
7.5.1 Interpolation	72
7.5.2 Extrapolation	72
7.5.3 Definition of the averaging volume.....	72

7.5.4	Searching for the maxima	73
7.6	Time-period averaged SAR considerations.....	73
7.6.1	General	73
7.6.2	RF conducted power.....	73
7.6.3	Time-period averaged SAR measurement settings for SAR measurement methods	73
7.6.4	Exposure condition and test position considerations	74
7.6.5	Time-period averaged SAR for simultaneous transmission.....	74
7.6.6	TX factor assessment	74
7.6.7	SAR measurements	75
7.6.8	Uncertainty in TPAS evaluations.....	75
7.7	Proximity sensors considerations	76
7.7.1	General	76
7.7.2	Procedures for determining proximity sensor triggering distances.....	77
7.7.3	Procedure for determining proximity sensor coverage area.....	80
7.7.4	SAR measurement procedure involving proximity sensors	81
7.8	SAR correction for deviations of complex permittivity from targets	81
7.8.1	General	81
7.8.2	SAR correction formula.....	82
7.8.3	Uncertainty of the correction formula	83
7.9	Minimization of testing time.....	83
7.9.1	General	83
7.9.2	Fast SAR testing.....	84
7.9.3	SAR test reductions	89
8	Measurement uncertainty estimation.....	100
8.1	General.....	100
8.2	Requirements on the uncertainty evaluation.....	101
8.3	Description of uncertainty models	102
8.3.1	General	102
8.3.2	SAR measurement of a DUT	102
8.3.3	System validation and system check measurement.....	102
8.3.4	System check repeatability and reproducibility	102
8.3.5	Fast SAR testing (relative measurement).....	102
8.4	Parameters contributing to uncertainty	104
8.4.1	Measurement system errors.....	104
8.4.2	Phantom and device (DUT or validation antenna) errors	105
8.4.3	Corrections to the SAR result (if applied)	107
9	Measurement report	108
9.1	General.....	108
9.2	Items to be recorded in the measurement report	108
Annex A (normative)	SAR measurement system verification	112
A.1	Overview.....	112
A.2	System check	112
A.2.1	Purpose	112
A.2.2	Phantom set-up	113
A.2.3	System check antenna.....	113
A.2.4	System check antenna input power measurement.....	114
A.2.5	System check procedure.....	115
A.2.6	System check acceptance criteria.....	116

A.3	System validation.....	116
A.3.1	Purpose	116
A.3.2	Phantom set-up	116
A.3.3	System validation antennas	116
A.3.4	Input power measurement	117
A.3.5	System validation procedure.....	117
A.4	Fast SAR testing system validation and system check	119
A.4.1	General	119
A.4.2	Fast SAR testing system validation.....	119
A.4.3	Fast SAR testing system check.....	120
Annex B (informative)	SAR test reduction supporting information.....	122
B.1	General.....	122
B.2	Test reduction based on characteristics of DUT design	122
B.2.1	General	122
B.2.2	Statistical analysis overview	122
B.2.3	Analysis results	123
B.2.4	Conclusions.....	126
B.2.5	Expansion to multi-transmission antennas	126
B.3	Test reduction based on analysis of SAR results on other signal modulations	126
B.3.1	General	126
B.3.2	Analysis results	127
B.4	Test reduction based on SAR level analysis.....	128
B.4.1	General	128
B.4.2	Statistical analysis	129
B.4.3	Test reduction applicability example	132
B.5	Other statistical approaches to search for the high SAR test configurations	134
B.5.1	General	134
B.5.2	Test reductions based on a DOE	134
B.5.3	One factor at a time (OFAT) search	134
B.5.4	Analysis of unstructured data.....	134
Annex C (informative)	Measurement uncertainty of results obtained from specific fast SAR testing methods	135
C.1	General.....	135
C.2	Measurement uncertainty evaluation – contributing parameters	135
C.2.1	General	135
C.2.2	Probe calibration and system calibration drift.....	136
C.2.3	Isotropy	136
C.2.4	Probe positioning.....	137
C.2.5	Mutual sensor coupling	138
C.2.6	Scattering within the probe array	139
C.2.7	Sampling error	139
C.2.8	Array boundaries	139
C.2.9	Probe or probe array coupling with the DUT	139
C.2.10	Measurement system immunity / secondary reception	139
C.2.11	Deviations in phantom shape	140
C.2.12	Spatial variation in dielectric properties	140
C.2.13	Reconstruction	140
C.3	Uncertainty budget.....	140
Annex D (normative)	SAR system validation antennas	143

D.1	General antenna requirements	143
D.2	Standard dipole antenna	143
D.2.1	Mechanical description	143
D.2.2	Numerical target SAR values	146
D.3	Standard waveguide	148
D.3.1	Mechanical description	148
D.3.2	Numerical target SAR values	149
D.4	System validation antennas for below 150 MHz	149
D.4.1	General	149
D.4.2	Confined loop antenna	150
D.4.3	Meander dipole antenna	152
D.5	Orthogonal E-field source – VPIFA	153
D.5.1	Mechanical description	153
D.5.2	Numerical target SAR values	156
Annex E (normative)	Calibration and characterization of dosimetric (SAR) probes	157
E.1	Introductory remarks	157
E.2	Linearity	158
E.3	Assessment of the sensitivity of the dipole sensors	158
E.3.1	General	158
E.3.2	Two-step calibration procedures	158
E.3.3	One-step calibration procedure – reference antenna method	164
E.3.4	One-step calibration procedure – coaxial calorimeter method	168
E.4	Isotropy	170
E.4.1	Axial isotropy	170
E.4.2	Hemispherical isotropy	170
E.5	Lower detection limit	175
E.6	Boundary effect	176
E.7	Response time	176
Annex F (informative)	Example recipes for phantom tissue-equivalent media	177
F.1	General	177
F.2	Ingredients	177
F.3	Tissue-equivalent medium liquid formulas (permittivity/conductivity)	178
Annex G (normative)	Phantom specifications	180
G.1	Rationale for the phantom characteristics	180
G.1.1	General	180
G.1.2	Rationale for the SAM phantom	180
G.1.3	Rationale for the flat phantom	180
G.2	SAM phantom specifications	181
G.2.1	General SAM phantom specifications	181
G.2.2	SAM phantom shell specification	185
G.3	Flat phantom specifications	187
G.4	Justification of flat phantom dimensions	188
G.5	Rationale for tissue-equivalent media	191
G.6	Definition of a phantom coordinate system and a DUT coordinate system	193
Annex H (informative)	Measurement of the dielectric properties of tissue-equivalent media and uncertainty estimation	195
H.1	Overview	195
H.2	Measurement techniques	195
H.2.1	General	195

H.2.2	Instrumentation.....	195
H.2.3	General principles	195
H.3	Slotted coaxial transmission line	196
H.3.1	General	196
H.3.2	Equipment set-up	196
H.3.3	Measurement procedure	197
H.4	Contact coaxial probe	197
H.4.1	General	197
H.4.2	Equipment set-up	198
H.4.3	Measurement procedure	199
H.5	TEM transmission line.....	199
H.5.1	General	199
H.5.2	Equipment set-up	200
H.5.3	Measurement procedure	200
H.6	Dielectric properties of reference liquids	201
Annex I (informative)	Studies for potential hand effects on head SAR	204
I.1	Overview.....	204
I.2	Background.....	204
I.2.1	General	204
I.2.2	Hand phantoms	205
I.3	Summary of experimental studies	205
I.3.1	Experimental studies using fully compliant SAR measurement systems	205
I.3.2	Experimental studies using other SAR measurement systems	205
I.4	Summary of computational studies.....	206
I.5	Conclusions	206
Annex J (informative)	Skin enhancement factor	207
J.1	Background.....	207
J.2	Rationale	208
J.3	Simulations	208
J.4	Recommendation	209
Annex K (normative)	Application-specific phantoms	211
K.1	General.....	211
K.2	Phantom basic requirements.....	211
K.3	Examples of specific alternative phantoms.....	211
K.3.1	Face-down SAM phantom	211
K.3.2	Head-stand SAM phantom	212
K.3.3	Wrist phantom	212
K.4	Scanning and evaluation requirements.....	213
K.5	Uncertainty assessment	213
K.6	Reporting	213
Annex L (normative)	Fast compliance evaluations using a flat-bottom phantom with a curved corner (Uniphantom).....	214
L.1	General.....	214
L.2	Uniphantom	214
L.3	Device positions for compliance testing and definitions of handset shapes	214
L.3.1	General	214
L.3.2	Handsets with a straight form factor	215
L.3.3	Handsets with a clamshell form factor.....	215
L.4	Testing procedure	215

L.4.1	General	215
L.4.2	Handsets with straight form factors	215
L.4.3	Handsets with clamshell form factors	216
L.5	Uncertainty of SAR measurement results using Uniphantom	217
Annex M (informative)	Wired hands-free headset testing	218
M.1	Concept	218
M.2	Example results	219
M.3	Discussion	220
Annex N (informative)	Applying the head SAR test procedures	221
Annex O (normative)	Uncertainty analysis for measurement system manufacturers and calibration laboratories.....	224
O.1	Probe linearity and detection limits	224
O.2	Broadband signal uncertainty	225
O.3	Boundary effect.....	225
O.4	Field-probe readout electronics uncertainty.....	226
O.5	Signal step-response time uncertainty.....	226
O.6	Probe integration-time uncertainty	227
O.6.1	General	227
O.6.2	Probe integration-time uncertainty for periodic pulsed signals.....	227
O.6.3	Probe integration-time uncertainty for non-periodic signals	228
O.7	Contribution of mechanical constraints.....	228
O.7.1	Mechanical tolerances of the probe positioner (directions parallel to phantom surface).....	228
O.7.2	Probe positioning with respect to phantom shell surface	228
O.7.3	First-order approximation of exponential decay	229
O.8	Contribution of post-processing.....	229
O.8.1	General	229
O.8.2	Evaluation test functions.....	230
O.8.3	Data-processing algorithm uncertainty evaluations	232
O.9	Tissue-equivalent medium properties uncertainty.....	235
O.9.1	General	235
O.9.2	Medium density	235
O.9.3	Medium conductivity uncertainty	235
O.9.4	Medium permittivity uncertainty	235
O.9.5	Assessment of dielectric properties measurement uncertainties.....	235
O.9.6	Medium temperature uncertainty.....	237
Annex P (normative)	Post-processing techniques	239
P.1	Extrapolation and interpolation schemes	239
P.1.1	General	239
P.1.2	Extrapolation schemes.....	239
P.1.3	Interpolation schemes.....	239
P.2	Averaging scheme and maximum finding	239
P.2.1	Volume average schemes.....	239
P.2.2	Finding the psSAR and estimating the uncertainty	240
Annex Q (informative)	Rationale for time-period averaged SAR test procedure	241
Annex R (normative)	Measurement uncertainty analysis for testing laboratories	242
R.1	RF ambient conditions	242
R.2	Device positioning and holder uncertainties	242
R.2.1	General	242

R.2.2	Device holder perturbation uncertainty	243
R.2.3	DUT positioning uncertainty with a specific test device holder: Type A	244
R.3	Probe modulation response	244
R.4	Time-period averaged SAR	245
R.4.1	General	245
R.4.2	TX factor uncertainty	245
R.5	Measured SAR drift.....	246
R.5.1	General	246
R.5.2	Accounting for drift	246
R.6	SAR scaling uncertainty	247
Annex S (normative)	Validation antenna SAR measurement uncertainty	248
S.1	Deviation of experimental antennas	248
S.2	Other uncertainty contributions when using system validation antennas.....	248
Annex T (normative)	Interlaboratory comparisons	250
T.1	Purpose	250
T.2	Phantom set-up	250
T.3	Reference devices	250
T.4	Power set-up	250
T.5	Interlaboratory comparison – procedure	251
Annex U (informative)	Determination of the margin for compliance evaluation using the Uniphanom	252
U.1	General.....	252
U.2	Deviation of the psSAR measured using the Uniphanom from the psSAR measured using the SAM phantom.....	252
U.3	Determination of margin based on 95 % confidence interval.....	253
U.4	Examples of the determination of the margin factor.....	253
U.4.1	Margin for handsets with straight form factors at flat-bottom position	253
U.4.2	Margin for handsets with straight form factors (except smart phones at flat-bottom position).....	255
U.4.3	Margin for smart phones at flat-bottom position	257
U.4.4	Margin for smart phones at corner position	259
U.4.5	Margin for handsets with clamshell form factors at corner position.....	261
Annex V (informative)	Automatic input power level control for system validation	264
V.1	General.....	264
V.2	Operational mechanism of AIPLC	264
Annex W (informative)	LTE test configurations supporting information	266
W.1	General.....	266
W.2	Study 1	266
W.3	Study 2	268
W.4	Justifications of relative standard deviations	269
Bibliography		271
Figure 1 – Quick start guide.....		29
Figure 2 – Dimensions of the elliptical phantom		35
Figure 3 – Mounting of the DUT in the device holder using low-permittivity and low-loss foam to avoid changes of DUT performance by the holder material.....		37
Figure 4 – Designation of DUT reference points.....		41

Figure 5 – Measurements performed by shifting a large device over the efficient measurement area of the system including overlapping areas – in this case: six tests performed	42
Figure 6 – Test positions for body-worn devices	43
Figure 7 – Device with swivel antenna	44
Figure 8 – Test positions for body supported devices.....	45
Figure 9 – Test positions for desktop devices	47
Figure 10 – Test positions for front-of-face devices.....	48
Figure 11 – Test position for hand-held devices, not used at the head or torso	49
Figure 12 – Test position for limb-worn devices	49
Figure 13 – Test position for clothing-integrated wireless communication devices.....	50
Figure 14 – Possible test positions for a generic device	51
Figure 15 – Vertical and horizontal reference lines and reference points A and B on two example device types: a full touch-screen smart phone (left) and a DUT with a keypad (right)	53
Figure 16 – Cheek position of the DUT on the left side of SAM where the device position shall be maintained for the phantom test set-up	56
Figure 17 – Tilt position of the DUT on the left side of SAM	56
Figure 18 – An alternative form factor DUT with reference points and reference lines	57
Figure 19 – Block diagram of the tests to be performed	60
Figure 20 – Orientation of the probe with respect to the line normal to the phantom surface, for head and flat phantoms, shown at two different locations	64
Figure 21 – Measurement procedure for different types of correlated signals	72
Figure 22 – Positioning of the surfaces and edges of the DUT for determining the proximity sensor triggering distance	79
Figure 23 – Positioning of the edges of the DUT to determine proximity sensor triggering distance variations with the edge positioned at different angles from the perpendicular position.....	80
Figure 24 – Fast SAR Procedure A	87
Figure 25 – Fast SAR Procedure B	89
Figure 26 – Modified chart of Figure 19.....	93
Figure 27 – Use of conducted power for LTE mode selection, for Band 1 (1 920 MHz to 1 980 MHz) (MPR values are in dB)	97
Figure 28 – Use of conducted power for LTE mode selection, for Band 17 (704 MHz to 716 MHz) (MPR values are in dB)	98
Figure A.1 – Test set-up for the system check	114
Figure B.1 – Distribution of Tilt/Cheek.....	124
Figure B.2 – SAR relative to SAR in position with maximum SAR in GSM mode.....	128
Figure B.3 – Two points identifying the minimum distance between the position of the interpolated maximum SAR and the points at $0,6 \times SAR_{max}$	130
Figure B.4 – Histogram for D_{min} in the case of GSM 900 and iso-level at $0,6 \times SAR_{max}$	130
Figure B.5 – Histogram for random variable $Factor_{1g,1800}$	132
Figure D.1 – Mechanical details of the standard dipoles.....	145
Figure D.2 – Standard waveguide (dimensions are according to Table D.3)	148
Figure D.3 – Drawing of the CLA that corresponds to a resonant loop integrated in a metallic structure to isolate the resonant structure from the environment	150
Figure D.4 – Mechanical details of the meander dipoles for 150 MHz.....	152

Figure D.5 – VPIFA validation antenna	155
Figure D.6 – Mask for positioning VPIFAs	155
Figure E.1 – Experimental set-up for assessment of the sensitivity (conversion factor) using a vertically-oriented rectangular waveguide	162
Figure E.2 – Illustration of the antenna gain evaluation set-up	165
Figure E.3 – Schematic of the coaxial calorimeter system	169
Figure E.4 – Set-up to assess hemispherical isotropy deviation in tissue-equivalent medium	171
Figure E.5 – Alternative set-up to assess hemispherical isotropy deviation in tissue-equivalent medium	172
Figure E.6 – Experimental set-up for the hemispherical isotropy assessment	173
Figure E.7 – Conventions for dipole position (ζ) and polarization (θ)	174
Figure E.8 – Measurement of hemispherical isotropy with reference antenna	175
Figure G.1 – Illustration of dimensions in Table G.1 and Table G.2	182
Figure G.2 – Close up side view of phantom showing the ear region	184
Figure G.3 – Side view of the phantom showing relevant markings	185
Figure G.4 – Sagittally bisected phantom with extended perimeter (shown placed on its side as used for device SAR tests)	186
Figure G.5 – Picture of the phantom showing the central strip	186
Figure G.6 – Cross-sectional view of SAM at the reference plane	187
Figure G.7 – Dimensions of the flat phantom set-up used for deriving the minimal phantom dimensions for W and L for a given phantom depth D	189
Figure G.8 – FDTD predicted error in the 10 g psSAR as a function of the dimensions of the flat phantom compared with an infinite flat phantom at 800 MHz	190
Figure G.9 – Complex permittivity of human tissues compared to the phantom target properties	193
Figure G.10 – Example reference coordinate system for the left-ear ERP of the SAM phantom	194
Figure G.11 – Example coordinate system on a DUT	194
Figure H.1 – Slotted line set-up	196
Figure H.2 – An open-ended coaxial probe with inner and outer radii a and b , respectively	198
Figure H.3 – TEM line dielectric properties test set-up [85]	200
Figure J.1 – SAR and temperature increase (ΔT) distributions simulated for a three-layer (skin, fat, muscle) planar torso model	207
Figure J.2 – Statistical approach to protect 90 % of the population	209
Figure J.3 – psSAR skin enhancement factors	210
Figure K.1 – SAM face-down phantom	212
Figure K.2 – SAM head-stand phantom	212
Figure K.3 – Wrist phantom	213
Figure L.1 – Cross section of the unified phantom (Uniphantom) with its dimensions	214
Figure L.2 – Measurement positions of handsets with straight and clamshell form factors	215
Figure L.3 – Flow chart of testing procedure for handsets with straight form factors	216
Figure L.4 – Flow chart of testing procedure for handsets with clamshell form factors	217
Figure M.1 – Configuration of a personal wired hands-free headset	218

Figure M.2 – Configuration without a personal wired hands-free headset	219
Figure O.1 – Orientation and surface of averaging volume relative to phantom surface	235
Figure U.1 – Categories (classes) for comparison of the measured psSAR between the Uniphantom (SAR_{uni}) and the SAM phantom (SAR_{SAM})	252
Figure U.2 – Histogram of the deviation of the 10 g psSAR of 45 handsets with straight form factors positioned at the flat bottom of the Uniphantom	254
Figure U.3 – Histogram of the deviation of the 1 g psSAR of 40 handsets with straight form factors positioned at the flat bottom of the Uniphantom	255
Figure U.4 – Histogram of the deviation of the 10 g psSAR of 25 handsets with straight form factors positioned at the flat bottom of the Uniphantom	256
Figure U.5 – Histogram of the deviation of the 1 g psSAR from 20 handsets with straight form factors positioned at the flat bottom of the Uniphantom	257
Figure U.6 – Histogram of the deviation of the 10 g psSAR of 20 handsets with straight form factors or smart phones positioned at the flat bottom of the Uniphantom	258
Figure U.7 – Histogram of the deviation of the 1 g psSAR of 20 handsets with straight form factors or smart phones positioned at the flat bottom of the Uniphantom	259
Figure U.8 – Histogram of the deviation of the 10 g psSAR of 20 handsets with straight form factors or smart phones positioned at the corner of the Uniphantom	260
Figure U.9 – Histogram of the deviation of the 1 g psSAR of 19 handsets with straight form factors or smart phones positioned at the corner of the Uniphantom	261
Figure U.10 – Histogram of the deviation of the 10 g psSAR of 20 handsets with clamshell form factors at the corner of the Uniphantom	262
Figure U.11 – Histogram of the deviation of the 1 g psSAR of 19 handsets with clamshell form factors at the corner of the Uniphantom	263
Figure V.1 – Generated RF input power variations to operation time without and with application of AIPLC	264
Figure V.2 – The system block diagram of the AIPLC	265
Figure V.3 – Power variation characteristics by adjusting the amplifier or signal generator outputs	265
Figure W.1 – Low, middle, and high channels at 2 GHz band (Band 1)	267
Figure W.2 – RF conducted power versus 10 g psSAR	268
Figure W.3 – 1 g SAR as a function of RF conducted power in various test conditions	269
Table 1 – Evaluation plan checklist	28
Table 2 – Dielectric properties of the tissue-equivalent medium	32
Table 3 – Area scan parameters	63
Table 4 – Zoom scan parameters	63
Table 5 – Example method to determine the combined SAR value using Alternative 1	70
Table 6 – Root-mean-squared error SAR correction formula as a function of the maximum change in permittivity or conductivity [28]	83
Table 7 – Threshold values $TH(f)$ used in this proposed test reduction protocol	93
Table 8 – Divisors for common probability density functions (PDFs)	101
Table 9 – Uncertainty budget template for evaluating the uncertainty in the measured value of 1 g or 10 g psSAR from a DUT or validation antenna (N = normal, R = rectangular)	103
Table 10 – Uncertainty of Formula (8) (see 7.8.2) as a function of the maximum change in permittivity or conductivity	107
Table B.1 – The number of DUTs used for the statistical study	123

Table B.2 – Statistical analysis results of $P(\text{Tilt/Cheek} > x)$ for various x values	124
Table B.3 – Statistical analysis results of $P(\text{Tilt/Cheek} > x)$ for 1 g and 10 g psSAR	124
Table B.4 – Statistical analysis results of $P(\text{Tilt/Cheek} > x)$ for various antenna locations	125
Table B.5 – Statistical analysis results of $P(\text{Tilt/Cheek} > x)$ for various frequency bands	125
Table B.6 – Statistical analysis results of $P(\text{Tilt/Cheek} > x)$ for various device types	126
Table B.7 – Distance $D_{\min}^*$ for various “iso-level” values	130
Table B.8 – Experimental thresholds to have a 95 % probability that the maximum measured SAR value from the area scan will also have a psSAR	132
Table B.9 – SAR values from the area scan (GSM 900 band): Example 1	133
Table B.10 – SAR values from the area scan (GSM 900 band): Example 2	133
Table C.1 – Measurement uncertainty budget for relative SAR measurements using Class 2 fast SAR testing, for tests performed within one frequency band and modulation	141
Table C.2 – Measurement uncertainty budget for system check using Class 2 fast SAR testing	142
Table D.1 – Mechanical dimensions of the reference dipoles	146
Table D.2 – Numerical target SAR values (W/kg) for standard dipole and flat phantom	147
Table D.3 – Mechanical dimensions of the standard waveguide	148
Table D.4 – Numerical target SAR values for waveguides	149
Table D.5 – Numerical target SAR values for CLAs	151
Table D.6 – Mechanical dimensions of the reference meander dipole	152
Table D.7 – Numerical target SAR value (W/kg) for meander dipole	153
Table D.8 – Dimensions for VPIFA antennas at different frequencies	154
Table D.9 – Electric properties for the dielectric layers for VPIFA antennas	155
Table D.10 – Numerical target SAR values for VPIFAs on the flat phantom	156
Table E.1 – Uncertainty analysis for transfer calibration using temperature probes	160
Table E.2 – Guidelines for designing calibration waveguides	163
Table E.3 – Uncertainty analysis of the probe calibration in waveguide	164
Table E.4 – Uncertainty template for evaluation of reference antenna gain	166
Table E.5 – Uncertainty template for calibration using reference antenna	167
Table E.6 – Uncertainty components for probe calibration using thermal methods	170
Table F.1 – Suggested recipes for achieving target dielectric properties, 30 MHz to 900 MHz	178
Table F.2 – Suggested recipes for achieving target dielectric properties, 1 800 MHz to 10 000 MHz	179
Table G.1 – Dimensions used in deriving SAM phantom from the ARMY 90th percentile male head data (Gordon et al. [61])	183
Table G.2 – Additional SAM dimensions compared with selected dimensions from the ARMY 90th percentile male head data (Gordon et al. [61])—specialist head measurement section	183
Table G.3 – Parameters used for calculation of reference SAR values in Table D.2	190
Table H.1 – Parameters for calculating the dielectric properties of various reference liquids	202
Table H.2 – Dielectric properties of reference liquids at 20 °C	203
Table J.1 –psSAR correction factors	209

Table N.1 – SAR results tables for example test results in GSM 850 band	221
Table N.2 – SAR results tables for example test results in GSM 900 band	222
Table N.3 – SAR results tables for example test results in GSM 1800 band	222
Table N.4 – SAR results tables for example test results in GSM 1900 band	223
Table O.1 – Parameters for the reference function f_1 in Formula (O.12).....	231
Table O.2 – Reference SAR values from the distribution functions f_1 , f_2 , and f_3	232
Table O.3 – Example uncertainty template and example numerical values for permittivity (ϵ_r') and conductivity (σ) measurement.....	237
Table S.1 – Uncertainties relating to the deviations of the parameters of the standard waveguide from theory.....	248
Table S.2 – Other uncertainty contributions relating to the dipole antennas specified in Annex D.....	249
Table S.3 – Other uncertainty contributions relating to the standard waveguides specified in Annex D	249
Table U.1 – Summary of information to determine the margin for handsets with straight form factors positioned at the flat bottom of the Uniphantom	254
Table U.2 – Summary of information to determine the margin for handsets with straight form factors, including slide-type and bar handsets (except smart phones), positioned at the flat bottom of the Uniphantom	256
Table U.3 – Summary of information to determine the margin for the smart phones positioned at the flat bottom of the Uniphantom	258
Table U.4 – Summary of information to determine the margin for smart phones positioned at the corner of the Uniphantom	260
Table U.5 – Statistical analysis results of $P(\text{Tilt/Cheek} > x)$ for various device types	261
Table U.6 – Summary of information to determine the margin for handsets with clamshell form factors positioned at the corner of the Uniphantom	262
Table W.1 – Relative standard deviation of α found in Study 1 (without MPR)	267
Table W.2 – Maximum relative standard deviation of α found in Study 2 (with MPR)	269

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**MEASUREMENT PROCEDURE FOR THE ASSESSMENT OF SPECIFIC
ABSORPTION RATE OF HUMAN EXPOSURE TO RADIO FREQUENCY
FIELDS FROM HAND-HELD AND BODY-MOUNTED WIRELESS
COMMUNICATION DEVICES –****Part 1528: Human models, instrumentation, and procedures
(Frequency range of 4 MHz to 10 GHz)**

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.

IEEE Standards documents are developed within IEEE Societies and Standards Coordinating Committees of the IEEE Standards Association (IEEE SA) Standards Board. IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of IEEE and serve without compensation. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards. Use of IEEE Standards documents is wholly voluntary. *IEEE documents are made available for use subject to important notices and legal disclaimers (see <http://standards.ieee.org/IPR/disclaimers.html> for more information).*

IEC collaborates closely with IEEE in accordance with conditions determined by agreement between the two organizations. This Dual Logo International Standard was jointly developed by the IEC and IEEE under the terms of that agreement.

- 2) The formal decisions 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. The formal decisions of IEEE on technical matters, once consensus within IEEE Societies and Standards Coordinating Committees has been reached, is determined by a balanced ballot of materially interested parties who indicate interest in reviewing the proposed standard. Final approval of the IEEE standards document is given by the IEEE Standards Association (IEEE SA) Standards Board.
- 3) IEC/IEEE Publications have the form of recommendations for international use and are accepted by IEC National Committees/IEEE Societies in that sense. While all reasonable efforts are made to ensure that the technical content of IEC/IEEE Publications is accurate, IEC or IEEE 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 (including IEC/IEEE Publications) transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC/IEEE Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC and IEEE do not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC and IEEE are 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 IEEE or their directors, employees, servants or agents including individual experts and members of technical committees and IEC National Committees, or volunteers of IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE SA) Standards Board, 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/IEEE Publication or any other IEC or IEEE 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 implementation of this IEC/IEEE Publication may require use of material covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. IEC or IEEE shall not be held responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patent Claims or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

International Standard IEC/IEEE 62209-1528 has been prepared by IEC technical committee 106: Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure, in cooperation with the International Committee on Electromagnetic Safety of the IEEE Standards Association, under the IEC/IEEE Dual Logo Agreement.

This first edition of IEC/IEEE 62209-1528 cancels and replaces IEC 62209-1:2016, IEC 62209-2:2010, IEC 62209-2:2010/AMD1:2019 and IEEE Std 1528-2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) extension of the frequency range down to 4 MHz and up to 10 GHz;
- b) testing of devices with proximity sensors;
- c) application specific phantoms;
- d) device holder specifications;
- e) fast SAR testing procedures;
- f) test reduction procedures;
- g) LTE assessment procedure;
- h) revision of validation clause, including validation antennas;
- i) revision of SAR assessment procedure;
- j) time-average SAR measurement procedure;
- k) uncertainty analysis;

This publication is published as an IEC/IEEE Dual Logo standard.

This publication contains attached files in the form of the Fast SAR Wizard described in 7.9.2.2 as well as CAD files for the SAM phantom. These files are available at:

http://www.iec.ch/dyn/www/f?p=103:227:0:::FSP_ORG_ID,FSP_LANG_ID:1303,25.

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

The text of this standard is based on the following IEC documents:

FDIS	Report on voting
106/514/FDIS	106/520/RVD

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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

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

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

The objective of this document is to provide procedures for measuring the human exposure from devices intended to be used at a position near the human head or body. It was developed to provide procedures to evaluate electromagnetic field (EMF) exposures due to radio frequency (RF) transmitting devices used next to the ear, in front of the face, mounted on the body, operating in conjunction with other RF-transmitting and non-transmitting devices or accessories (e.g. belt-clips), or embedded in garments. The types of devices dealt with include but are not limited to mobile telephones, cordless telephones, cordless microphones, and radio transmitters in personal computers. The applicable frequency range is from 4 MHz to 10 GHz. The document defines:

- measurement system requirements (Clause 6),
- SAR measurement protocols (Clause 7),
- SAR measurement uncertainty evaluation (Clause 8), and
- reporting requirements (Clause 9).

At the time this document was developed, two computational and measurement joint IEC/IEEE projects dealing with millimetre-wave power density assessment were under development, covering the frequency range from 6 GHz to 300 GHz. Hence there is an overlap of frequency between this document, which deals with SAR, and the other joint IEC/IEEE projects dealing with power density from 6 GHz to 10 GHz. The IEC/IEEE joint working group was aware of this fact and believed that it would give the flexibility of using whatever metrics suitable for the considered case of compliance assessment.

MEASUREMENT PROCEDURE FOR THE ASSESSMENT OF SPECIFIC ABSORPTION RATE OF HUMAN EXPOSURE TO RADIO FREQUENCY FIELDS FROM HAND-HELD AND BODY-MOUNTED WIRELESS COMMUNICATION DEVICES –

Part 1528: Human models, instrumentation, and procedures (Frequency range of 4 MHz to 10 GHz)

1 Scope

This document specifies protocols and test procedures for the reproducible and repeatable measurement of the conservative exposure peak spatial average SAR (psSAR) induced inside a simplified model of the head and the body by radio-frequency (RF) transmitting devices, with a defined measurement uncertainty. These protocols and procedures apply to a significant majority of the population, including children, during the use of hand-held and body-worn wireless communication devices. These devices include single or multiple transmitters or antennas, and are operated with their radiating structure(s) at distances up to 200 mm from a human head or body. This document is employed to evaluate SAR compliance of different types of wireless communication devices used next to the ear, in front of the face, mounted on the body, operating in conjunction with other RF-transmitting, non-transmitting devices or accessories (e.g. belt-clips), or embedded in garments. The applicable frequency range is from 4 MHz to 10 GHz. Devices operating in the applicable frequency range can be tested using the phantoms and other requirements defined in this document.

The device categories covered include, but are not limited to, mobile telephones, cordless microphones, and radio transmitters in personal, desktop and laptop computers, for multi-band operations using single or multiple antennas, including push-to-talk devices. This document can also be applied for wireless power transfer devices operating above 4 MHz.

This document does not apply to implanted medical devices.

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 62209-3:2019, *Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Part 3: Vector measurement-based systems (Frequency range of 600 MHz to 6 GHz).*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*