
Merilni postopki za ocenjevanje stopnje specifične absorpcije pri izpostavljenosti ljudi elektromagnetnim sevanjem brezžičnih komunikacijskih naprav, ki se držijo v roki ali pritrdijo na telo - 1528. del: Modeli človeka, instrumenti in postopki (frekvenčno območje od 4 MHz do 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)

PREVIEW
(standards.iteh.ai)

<https://standards.iteh.ai/catalog/standards/sist/bd66cf3b-da5d-48fc-97cd-c9a4043e7e10/osist-pren-iec-ieee-62209-1528-2020>

Ta slovenski standard je istoveten z: prEN IEC/IEEE 62209-1528

ICS:

13.280	Varstvo pred sevanjem	Radiation protection
33.050.10	Telefonska oprema	Telephone equipment

oSIST prEN IEC/IEEE 62209-1528:2020 en

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[oSIST prEN IEC/IEEE 62209-1528:2020](https://standards.iteh.ai/catalog/standards/sist/bd66cf3b-da5d-48fc-97cd-c9a4043e7e10/osist-pren-iec-ieee-62209-1528-2020)
<https://standards.iteh.ai/catalog/standards/sist/bd66cf3b-da5d-48fc-97cd-c9a4043e7e10/osist-pren-iec-ieee-62209-1528-2020>



106/514/FDIS

FINAL DRAFT INTERNATIONAL STANDARD (FDIS)

PROJECT NUMBER: IEC/IEEE 62209-1528 ED1	
DATE OF CIRCULATION: 2020-04-10	CLOSING DATE FOR VOTING: 2020-05-22
SUPERSEDES DOCUMENTS: 106/464/CDV, 106/475C/RVC	

IEC TC 106 : METHODS FOR THE ASSESSMENT OF ELECTRIC, MAGNETIC AND ELECTROMAGNETIC FIELDS ASSOCIATED WITH HUMAN EXPOSURE	
SECRETARIAT: Germany	SECRETARY: Mr Diego Cuartielles
OF INTEREST TO THE FOLLOWING COMMITTEES: TC 9,TC 27,TC 29,TC 34,SC 62A,SC 62B,TC 69,TC 77,TC 79,TC 96,TC 100,TC 124,CISPR	HORIZONTAL STANDARD: <input type="checkbox"/>
FUNCTIONS CONCERNED: <input type="checkbox"/> EMC <input type="checkbox"/> ENVIRONMENT <input type="checkbox"/> QUALITY ASSURANCE <input type="checkbox"/> SAFETY	
<input type="checkbox"/> SUBMITTED FOR CENELEC PARALLEL VOTING	<input checked="" type="checkbox"/> NOT SUBMITTED FOR CENELEC PARALLEL VOTING

FINAL STANDARD PREVIEW
(standards.iteh.ai)

oSIST prEN IEC/IEEE 62209-1528:2020
<https://standards.iteh.ai/catalog/standards/sist/bd66cf3b-da5d-48fc-97cd-c9a4043e7e10/osist-pren-iec-ieee-62209-1528-2020>

This document is a draft distributed for approval. It may not be referred to as an International Standard until published as such.

In addition to their evaluation as being acceptable for industrial, technological, commercial and user purposes, Final Draft International Standards may on occasion have to be considered in the light of their potential to become standards to which reference may be made in national regulations.

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

TITLE: 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)
--

PROPOSED STABILITY DATE: 2022

NOTE FROM TC/SC OFFICERS:

Copyright © 2020 International Electrotechnical Commission, IEC. All rights reserved. It is permitted to download this electronic file, to make a copy and to print out the content for the sole purpose of preparing National Committee positions. You may not copy or "mirror" the file or printed version of the document, or any part of it, for any other purpose without permission in writing from IEC.

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

ITC STANDARD PREVIEW
 (standards.iteh.ai)
 oSIST prEN IEC/IEEE 62209-1528:2020
<https://standards.iteh.ai/catalog/standards/sist/bd66cf3b-da5d-48fc-97cd-c9a4043c7e10/osist-pr-en-iec-ieee-62209-1528-2020>

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 Uniphantom	252
U.1	General.....	252
U.2	Deviation of the psSAR measured using the Uniphantom 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 $P(\text{Tilt/Cheek} > \alpha)$ 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