APPENDIX D: MEASUREMENT UNCERTAINTIES

Applicable for SAR measurements with MAGPy-H3D probe and Module WPT

Item	Uncertainty Source	Tolerance (dB)	Distr.	Div.	ci	Std.Unc. (dB)
Probe uncertainty						
1	Amplitude calibration uncertainty	0.47	norm	1	1	0.47
2	Gradient calibration uncertainty	N/A	norm	1	1	N/A
3	Probe anisotropy	0.5	rect	$\sqrt{3}$	1	0.29
4	Probe dynamic linearity	0.15	rect	$\sqrt{3}$	1	0.09
5	Probe frequency domain response	0.25	rect	$\sqrt{3}$	1	0.14
6	Modulation response	N/A	rect	$\sqrt{3}$	1	N/A
7	Spatial averaging (maximum gradient)	N/A	rect	$\sqrt{3}$	1	N/A
8	Gradient uncertainty	0.1	rect	$\sqrt{3}$	1	0.06
9	Gradient detection uncertainty	N/A	rect	$\sqrt{3}$	1	N/A
10	Parasitic E-field sensitivity	0.1	rect	$\sqrt{3}$	1	0.06
11	Detection limit	0.15	rect	$\sqrt{3}$	1	0.09
12	Readout electronics	0	norm	1	1	0
13	Response time	N/A	norm	1	1	N/A
14	Probe positioning	0.19	norm	1	1	0.19
15	Shaping, filtering, signal conditioning	N/A	norm	1	1	N/A
16	Nominal position	N/A	rect	$\sqrt{3}$	1	N/A
17	Repeatibility	0.1	norm	1	1	0.10
Numerical simulations						
18	Numerical method	0	rect	$\sqrt{3}$	1	0
19	Grid resolution	0.02	rect	$\sqrt{3}$	1	0.01
20	Tissue parameters	N/A	rect	$\sqrt{3}$	1	N/A
21	Averaging method	0.05	rect	$\sqrt{3}$	1	0.03
22	Model and exposure location	0	rect	$\sqrt{3}$	1	0
23	Convergence	0	rect	$\sqrt{3}$	1	0
24	Boundary conditions	0.2	rect	$\sqrt{3}$	1	0.12
25	Post-processing, interpolation	0.30	rect	$\sqrt{3}$	1	0.17
Field reconstruction						
26	Reconstruction algorithm; i.e., calculation of vector potential from measured magnetic flux density	0.09	rect	$\sqrt{3}$	1	0.05
	Combined uncertainty (k=1)					0.66
	Expanded uncertainty (k=2)					1.31

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Applicable for SAR measurements with EX3DVx Probe:

a	b	c	d	e= f(d,k)	f	g	h = c x f/e	i = c x g/e	k
Uncertainty Component	IEEE 1528 Sec.	Tol. (± %)	Prob. Dist.	Div.	c_i 1gm	c_i 10 gms	1gm u_i (± %)	10gms u_i (± %)	v_i
Measurement System									
Probe Calibration	E.2.1	9.3	N	1	1	1	9.3	9.3	∞
Axial Isotropy	E.2.2	0.25	N	1	0.7	0.7	0.2	0.2	∞
Hemishperical Isotropy	E.2.2	1.3	N	1	0.7	0.7	0.9	0.9	∞
Boundary Effect	E.2.3	2	R	1.732	1	1	1.2	1.2	∞
Linearity	E.2.4	0.3	N	1	1	1	0.3	0.3	∞
System Detection Limits	E.2.4	0.25	R	1.732	1	1	0.1	0.1	∞
Readout Electronics	E.2.6	0.3	N	1	1	1	0.3	0.3	∞
Response Time	E.2.7	0.8	R	1.732	1	1	0.5	0.5	∞
Integration Time	E.2.8	2.6	R	1.732	1	1	1.5	1.5	∞
RF Ambient Conditions - Noise	E.6.1	3	R	1.732	1	1	1.7	1.7	∞
RF Ambient Conditions - Reflections	E.6.1	3	R	1.732	1	1	1.7	1.7	∞
Probe Positioner Mechanical Tolerance	E.6.2	0.4	R	1.732	1	1	0.2	0.2	∞
Probe Positioning w/ respect to Phantom	E.6.3	6.7	R	1.732	1	1	3.9	3.9	∞
Extrapolation, Interpolation & Integration algorithms for Max. SAR Evaluation	E.5	4	R	1.732	1	1	2.3	2.3	∞
Test Sample Related									
Test Sample Positioning	E.4.2	2.70	N	1	1	1	2.7	2.7	35
Device Holder Uncertainty	E.4.1	1.67	N	1	1	1	1.7	1.7	5
Output Power Variation - SAR drift measurement	E.2.9	5	R	1.732	1	1	2.9	2.9	∞
SAR Scaling	E.6.5	0	R	1.732	1	1	0.0	0.0	∞
Phantom & Tissue Parameters									
Phantom Uncertainty (Shape & Thickness tolerances)	E.3.1	7.6	R	1.73	1.0	1.0	4.4	4.4	∞
Liquid Conductivity - measurement uncertainty	E.3.3	4.2	N	1	0.78	0.71	3.3	3.0	76
Liquid Permittivity - measurement uncertainty	E.3.3	4.1	N	1	0.23	0.26	0.9	1.1	75
Liquid Conductivity - Temperature Uncertainty	E.3.4	3.4	R	1.732	0.78	0.71	1.5	1.4	∞
Liquid Permittivity - Temperature Unceritainty	E.3.4	0.6	R	1.732	0.23	0.26	0.1	0.1	∞
Liquid Conductivity - deviation from target values	E.3.2	5.0	R	1.73	0.64	0.43	1.8	1.2	∞
Liquid Permittivity - deviation from target values	E.3.2	5.0	R	1.73	0.60	0.49	1.7	1.4	∞
Combined Standard Uncertainty (k=1)			RSS				13.3	13.1	191
Expanded Uncertainty (95% CONFIDENCE LEVEL)			k=2				26.5	26.1	

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Applicable for Power Density Measurements:

a	b	c	d	e	f = c x f/e	g
Uncertainty Component	Unc. (± dB)	Prob. Dist.	Div.	c_i	u_i (± dB)	v_i
Measurement System						
Calibration	0.49	N	1	1	0.49	∞
Probe Correction	0.00	R	1.73	1	0.00	∞
Frequency Response	0.20	R	1.73	1	0.12	∞
Sensor Cross Coupling	0.00	R	1.73	1	0.00	∞
Isotropy	0.50	R	1.73	1	0.29	∞
Linearity	0.20	R	1.73	1	0.12	∞
Probe Scattering	0.00	R	1.73	1	0.00	∞
Probe Positioning offset	0.30	R	1.73	1	0.17	∞
Probe Positioning Repeatability	0.04	R	1.73	1	0.02	∞
Sensor MechanicalOffset	0.00	R	1.73	1	0.00	∞
Probe Spatial Resolution	0.00	R	1.73	1	0.00	∞
Field Impedence Dependance	0.00	R	1.73	1	0.00	∞
Amplitude and Phase Drift	0.00	R	1.73	1	0.00	∞
Amplitude and Phase Noise	0.04	R	1.73	1	0.02	∞
Measurement Area Truncation	0.00	R	1.73	1	0.00	∞
Data Acquisition	0.03	N	1	1	0.03	∞
Sampling	0.00	R	1.73	1	0.00	∞
Field Reconstruction	2.00	R	1.73	1	1.15	∞
Forward Transformation	0.00	R	1.73	1	0.00	∞
Power Density Scaling	0.00	R	1.73	1	0.00	∞
Spatial Averaging	0.10	R	1.73	1	0.06	∞
System Detection Limit	0.04	R	1.73	1	0.02	∞
Test Sample Related						
Probe Coupling with DUT	0.00	R	1.73	1	0.00	∞
Modulation Response	0.40	R	1.73	1	0.23	∞
Integration Time	0.00	R	1.73	1	0.00	∞
Response Time	0.00	R	1.73	1	0.00	∞
Device Holder Influence	0.10	R	1.73	1	0.06	∞
DUT alignment	0.00	R	1.73	1	0.00	∞
RF Ambient Conditions	0.04	R	1.73	1	0.02	∞
Ambient Reflections	0.04	R	1.73	1	0.02	∞
Immunity/Secondary Reception	0.00	R	1.73	1	0.00	∞
Drift of DUT	0.21	R	1.73	1	0.12	∞
Combined Standard Uncertainty (k=1)		RSS			1.34	∞
Expanded Uncertainty (95% CONFIDENCE LEVEL)		k=2			2.68	

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