



Element Materials Technology

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PART 0 SAR CHAR REPORT

Applicant Name:

Apple, Inc.
One Apple Park Way
Cupertino, CA 95014

Date of Testing:

12/09/2023 – 03/02/2024

Test Report Issue Date:

03/21/2024

Test Site/Location:

Element, Morgan Hill, CA, USA

Document Serial No.:

1C2311270066-01.BCG

FCC ID:

BCGA2899

APPLICANT:

APPLE, INC.

Report Type:

Part 0 SAR Characterization

DUT Type:

Tablet Device

Model(s):

A2899

I attest to the accuracy of data. All measurements reported herein were performed by me or were made under my supervision and are correct to the best of my knowledge and belief. I assume full responsibility for the completeness of these measurements and vouch for the qualifications of all persons taking them.

Test results reported herein relate only to the item(s) tested.

RJ Ortanez
Executive Vice President

Prepared by: WKR:0000000981

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1 DEVICE UNDER TEST

1.1 Device Overview

Band & Mode	Operating Modes	Tx Frequency
UMTS 850	Data	826.4 - 846.6 MHz
UMTS 1750	Data	1712.4 - 1752.6 MHz
UMTS 1900	Data	1852.4 - 1907.6 MHz
LTE Band 71	Data	665.5 - 695.5 MHz
LTE Band 12	Data	699.7 - 715.3 MHz
LTE Band 17	Data	706.5 - 713.5 MHz
LTE Band 13	Data	779.5 - 784.5 MHz
LTE Band 14	Data	790.5 - 795.5 MHz
LTE Band 26 (Cell)	Data	814.7 - 848.3 MHz
LTE Band 5 (Cell)	Data	824.7 - 848.3 MHz
LTE Band 66 (AWS)	Data	1710.7 - 1779.3 MHz
LTE Band 4 (AWS)	Data	1710.7 - 1754.3 MHz
LTE Band 25 (PCS)	Data	1850.7 - 1914.3 MHz
LTE Band 2 (PCS)	Data	1850.7 - 1909.3 MHz
LTE Band 30	Data	2307.5 - 2312.5 MHz
LTE Band 7	Data	2502.5 - 2567.5 MHz
LTE Band 41	Data	2498.5 - 2687.5 MHz
LTE Band 48	Data	3552.5 - 3697.5 MHz
NR Band n71	Data	665.5 - 695.5 MHz
NR Band n12	Data	701.5 - 713.5 MHz
NR Band n14	Data	790.5 - 795.5 MHz
NR Band n26 (Cell)	Data	816.5 - 846.5 MHz
NR Band n5 (Cell)	Data	826.5 - 846.5 MHz
NR Band n70	Data	1697.5 - 1707.5 MHz
NR Band n66 (AWS)	Data	1712.5 - 1777.5 MHz
NR Band n25 (PCS)	Data	1852.5 - 1912.5 MHz
NR Band n2 (PCS)	Data	1852.5 - 1907.5 MHz
NR Band n30	Data	2307.5 - 2312.5 MHz
NR Band n7	Data	2502.5 - 2567.5 MHz
NR Band n41	Data	2506.02 - 2679.99 MHz
NR Band n48	Data	3555.0 - 3694.98 MHz
NR Band n77 DoD	Data	3455.01 - 3544.98 MHz
NR Band n77 C	Data	3705.0 - 3975.0 MHz
2.4 GHz WLAN	Voice/Data	2412 - 2472 MHz
5 GHz WIFI	Voice/Data	U-NII-1: 5180 - 5240 MHz U-NII-2A: 5260 - 5320 MHz U-NII-2C: 5500 - 5720 MHz U-NII-3: 5745 - 5825 MHz
6 GHz WIFI	Voice/Data	U-NII-5: 5955 - 6415 MHz U-NII-6: 6435 - 6515 MHz U-NII-7: 6535 - 6875 MHz U-NII-8: 6895 - 7115 MHz
Bluetooth	Data	2402 - 2480 MHz
802.15.4	Data	2405 - 2475 MHz
NB UNII-1	Data	5162 - 5245 MHz
NB UNII-3	Data	5733 - 5844 MHz
WPT	N/A	13.56 MHz

This device uses the Qualcomm® Gen2 Smart Transmit feature to control and manage transmitting power in real time and to ensure the time-averaged RF exposure is in compliance with the FCC requirement at all times for 3G/4G/5G WWAN operations. Additionally, this device supports WLAN/BT/802.15.4/NB-UNII technologies, but the output power of these modems is not controlled by the Smart Transmit algorithm.

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1.2 Time-Averaging for SAR and Power Density

This device is enabled with Qualcomm® Gen2 Smart Transmit algorithm to control and manage transmitting power in real time and to ensure that the time-averaged RF exposure from 3G/4G/5G Sub-6 NR WWAN is in compliance with FCC requirements. This Part 0 report shows SAR characterization of WWAN radios for 3G/4G/5G Sub-6 NR. Characterization is achieved by determining P_{Limit} for 3G/4G/5G Sub-6 NR that corresponds to the exposure design targets after accounting for all device design related uncertainties, i.e., SAR_design_target (< FCC SAR limit) for sub-6 radio. The SAR characterization is denoted as SAR Char in this report. Section 1.3 includes a nomenclature of the specific terms used in this report.

The compliance test under the static transmission scenario and simultaneous transmission analysis are reported in Part 1 report. The validation of the time-averaging algorithm and compliance under the dynamic (time- varying) transmission scenario for WWAN technologies are reported in Part 2 report (report SN could be found in Section 1.4 – Bibliography).

1.3 Nomenclature for Part 0 Report

Technology	Term	Description
3G/4G/5G Sub-6 NR	P_{limit}	Power level that corresponds to the exposure design target (SAR_design_target) after accounting for all device design related uncertainties
	P_{max}	Maximum tune up output power
	SAR_design_target	Target SAR level < FCC SAR limit after accounting for all device design related uncertainties
	SAR Char	Table containing P_{limit} for all technologies and bands

1.4 Bibliography

Report Type	Report Serial Number
FCC SAR Evaluation Report	1C2311270066-02.BCG
RF Exposure Part 2 Test Report	1C2311270066-03.BCG
RF Exposure Compliance Summary	1C2311270066-04.BCG

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2 SAR MEASUREMENTS

2.1 SAR Definition

Specific Absorption Rate is defined as the time derivative (rate) of the incremental energy (dU) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dV) of a given density (ρ). It is also defined as the rate of RF energy absorption per unit mass at a point in an absorbing body (see Equation 2-1).

Equation 2-1
SAR Mathematical Equation

$$SAR = \frac{d}{dt} \left(\frac{dU}{dm} \right) = \frac{d}{dt} \left(\frac{dU}{\rho dv} \right)$$

SAR is expressed in units of Watts per Kilogram (W/kg).

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

where:

σ	=	conductivity of the tissue-simulating material (S/m)
ρ	=	mass density of the tissue-simulating material (kg/m ³)
E	=	Total RMS electric field strength (V/m)

NOTE: The primary factors that control rate of energy absorption were found to be the wavelength of the incident field in relation to the dimensions and geometry of the irradiated organism, the orientation of the organism in relation to the polarity of field vectors, the presence of reflecting surfaces, and whether conductive contact is made by the organism with a ground plane.[6]

2.2 SAR Measurement Procedure

The evaluation was performed using the following procedure compliant to FCC KDB Publication 865664 D01v01r04 and IEEE 1528-2013:

1. The SAR distribution at the exposed side of the head or body was measured at a distance no greater than 5.0 mm from the inner surface of the shell. The area covered the entire dimension of the device-head and body interface and the horizontal grid resolution was determined per FCC KDB Publication 865664 D01v01r04 (See Table) and IEEE 1528-2013.
2. The point SAR measurement was taken at the maximum SAR region determined from Step 1 to enable the monitoring of SAR fluctuations/drifts during the 1g/10g cube evaluation. SAR at this fixed point was measured and used as a reference value.
3. Based on the area scan data, the peak of the region with maximum SAR was determined by spline interpolation. Around this point, a volume was assessed according to the measurement resolution and volume size requirements of FCC KDB Publication 865664 D01v01r04 (See Table) and IEEE 1528-2013. On the

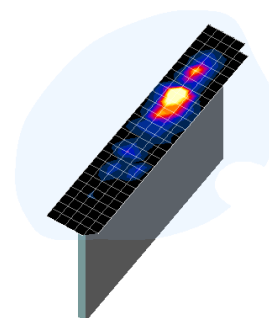


Figure 2-1
Sample SAR Area Scan

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basis of this data set, the spatial peak SAR value was evaluated with the following procedure (see references or the DASY manual online for more details):

a. SAR values at the inner surface of the phantom are extrapolated from the measured values along the line away from the surface with spacing no greater than that in Table . The extrapolation was based on a least-squares algorithm. A polynomial of the fourth order was calculated through the points in the z-axis (normal to the phantom shell).

b. After the maximum interpolated values were calculated between the points in the cube, the SAR was averaged over the spatial volume (1g or 10g) using a 3D-Spline interpolation algorithm. The 3D-spline is composed of three one-dimensional splines with the “Not a knot” condition (in x, y, and z directions). The volume was then integrated with the trapezoidal algorithm. One thousand points (10 x 10 x 10) were obtained through interpolation, in order to calculate the averaged SAR.

c. All neighboring volumes were evaluated until no neighboring volume with a higher average value was found.

4. The SAR reference value, at the same location as step 2, was re-measured after the zoom scan was complete to calculate the SAR drift. If the drift deviated by more than 5%, the SAR test and drift measurements were repeated.

Table 2-1
Area and Zoom Scan Resolutions per FCC KDB Publication 865664 D01v01r04*

Frequency	Maximum Area Scan Resolution (mm) ($\Delta x_{\text{area}}, \Delta y_{\text{area}}$)	Maximum Zoom Scan Resolution (mm) ($\Delta x_{\text{zoom}}, \Delta y_{\text{zoom}}$)	Maximum Zoom Scan Spatial Resolution (mm)			Minimum Zoom Scan Volume (mm) (x,y,z)
			Uniform Grid	Graded Grid		
				$\Delta z_{\text{zoom}}(n)$	$\Delta z_{\text{zoom}}(1)^*$	
≤ 2 GHz	≤ 15	≤ 8	≤ 5	≤ 4	≤ 1.5* $\Delta z_{\text{zoom}}(n-1)$	≥ 30
2-3 GHz	≤ 12	≤ 5	≤ 5	≤ 4	≤ 1.5* $\Delta z_{\text{zoom}}(n-1)$	≥ 30
3-4 GHz	≤ 12	≤ 5	≤ 4	≤ 3	≤ 1.5* $\Delta z_{\text{zoom}}(n-1)$	≥ 28
4-5 GHz	≤ 10	≤ 4	≤ 3	≤ 2.5	≤ 1.5* $\Delta z_{\text{zoom}}(n-1)$	≥ 25
5-6 GHz	≤ 10	≤ 4	≤ 2	≤ 2	≤ 1.5* $\Delta z_{\text{zoom}}(n-1)$	≥ 22

*Also compliant to IEEE 1528-2013 Table 6

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3 SAR CHARACTERIZATION

3.1 DSI and SAR Determination

This device uses different Device State Index (DSI) to configure different time averaged power levels based on certain exposure scenarios. Depending on the detection scheme implemented in the tablet, the worst-case SAR was determined by measurements for the relevant exposure conditions for that DSI. Detailed descriptions of the detection mechanisms are included in the operational description.

The device state index (DSI) conditions used in Table 3-1 represent different exposure scenarios.

Table 3-1
DSI and Corresponding Exposure Scenarios

Scenario	Description	SAR Test Cases
(DSI = 1)	▪ Device on body	Tablet SAR per KDB Publication 616217 D04

3.2 SAR Design Target

SAR_design_target is determined by ensuring that it is less than FCC SAR limit after accounting for uncertainties specified by the manufacturer (see Table 3-2).

Table 3-2
***SAR_design_target* Calculations**

1g SAR (W/kg)	
<i>Smart tx Uncertainty</i>	1.0 dB
<i>SAR_regulatory_limit</i>	1.6 W/kg
<i>SAR_design_target</i>	0.8 W/kg

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3.3 SAR Char

SAR test results corresponding to P_{max} for each antenna/technology/band/DSI can be found in FCC SAR Part 1 Report.

P_{limit} is calculated by linearly scaling with the measured SAR at the P_{part0} to correspond to the SAR_{design_target} . When $P_{limit} < P_{max}$, P_{part0} was used as P_{limit} in the Smart Transmit EFS. When $P_{limit} > P_{max}$ and $P_{part0}=P_{max}$, calculated P_{limit} was used in the Smart Transmit EFS. All reported SAR obtained from the P_{part0} SAR tests was less than $SAR_{Design_target}+ 1$ dB Uncertainty. The final P_{limit} determination for each exposure scenario corresponding to SAR_{design_target} are shown in Table 3-3.

Table 3-3
 P_{Limit} Determination

Device State Index (DSI)	P_{Limit} Determination Scenarios
1	The worst-case SAR exposure is determined as maximum SAR normalized to the limit among: 1. Tablet SAR measured at 0 mm for Back, Top, Bottom, Right, Left surfaces

Note:

For DSI = 1, P_{limit} is calculated by:

P_{limit} corresponding to 1g Tablet SAR evaluation at 0 mm for back, top, bottom, left and right surfaces

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Table 3-4
SAR Characterizations

Exposure Scenario:	Ant 1a	Ant 1a	Ant 1b	Ant 1b	Ant 2	Ant 2	Ant 3a	Ant 3a	Ant 3b	Ant 3b	Ant 4	Ant 4
Averaging Volume:	1g	Maximum Tune up Output Power*	1g	Maximum Tune up Output Power*	1g	Maximum Tune up Output Power*	1g	Maximum Tune up Output Power*	1g	Maximum Tune up Output Power*	1g	Maximum Tune up Output Power*
Spacing:	0 mm		0 mm		0 mm		0 mm		0 mm		0 mm	
DSI:	1		1		1		1		1		1	
Technology/Band	Plimit corresponding to 0.8 W/kg	Pmax	Plimit corresponding to 0.8 W/kg	Pmax	Plimit corresponding to 0.8 W/kg	Pmax	Plimit corresponding to 0.8 W/kg	Pmax	Plimit corresponding to 0.8 W/kg	Pmax	Plimit corresponding to 0.8 W/kg	Pmax
UMTS 850	N/A	N/A	N/A	N/A	18.80	24.00	N/A	N/A	N/A	N/A	19.00	25.00
UMTS 1750	N/A	N/A	12.00	22.00	14.50	23.00	N/A	N/A	12.50	24.00	14.60	25.00
UMTS 1900	N/A	N/A	10.90	22.00	14.60	23.00	N/A	N/A	12.00	24.00	13.70	25.00
LTE Band 71	N/A	N/A	N/A	N/A	20.20	24.00	N/A	N/A	N/A	N/A	20.00	25.00
LTE Band 12	N/A	N/A	N/A	N/A	19.30	24.00	N/A	N/A	N/A	N/A	19.10	25.00
LTE Band 17	N/A	N/A	N/A	N/A	19.30	24.00	N/A	N/A	N/A	N/A	19.10	25.00
LTE Band 13	N/A	N/A	N/A	N/A	19.20	24.00	N/A	N/A	N/A	N/A	20.80	25.00
LTE Band 14	N/A	N/A	N/A	N/A	19.20	24.00	N/A	N/A	N/A	N/A	20.80	25.00
LTE Band 26	N/A	N/A	N/A	N/A	18.80	24.00	N/A	N/A	N/A	N/A	19.00	25.00
LTE Band 5	N/A	N/A	N/A	N/A	18.80	24.00	N/A	N/A	N/A	N/A	19.00	25.00
LTE Band 5 ULCA	N/A	N/A	N/A	N/A	18.80	24.00	N/A	N/A	N/A	N/A	19.00	25.00
LTE Band 4	N/A	N/A	12.00	25.00	14.50	24.50	N/A	N/A	12.50	24.50	14.60	25.00
LTE Band 66	N/A	N/A	12.00	25.00	14.50	24.80	N/A	N/A	12.50	24.80	14.60	25.00
LTE Band 2	N/A	N/A	10.90	22.00	14.60	23.00	N/A	N/A	12.00	24.00	13.70	25.00
LTE Band 25	N/A	N/A	10.90	22.00	14.60	23.00	N/A	N/A	12.00	24.00	13.70	25.00
LTE Band 30	N/A	N/A	12.30	21.50	13.00	20.05	N/A	N/A	12.10	21.80	14.50	25.00
LTE Band 7	N/A	N/A	11.40	21.50	11.30	22.00	N/A	N/A	11.10	24.00	10.80	25.00
LTE Band 7 ULCA	N/A	N/A	11.40	21.50	11.30	22.00	N/A	N/A	11.10	24.00	10.80	25.00
LTE Band 38	N/A	N/A	13.50	25.00	13.90	25.00	N/A	N/A	14.00	25.00	12.60	25.00
LTE Band 38 ULCA	N/A	N/A	13.50	25.00	13.90	25.00	N/A	N/A	14.00	25.00	12.60	25.00
LTE Band 41 (PC3)	N/A	N/A	11.5	23.0	11.9	23.0	N/A	N/A	12.0	23.0	10.6	23.0
LTE Band 41 (PC3) ULCA	N/A	N/A	11.5	23.0	11.9	23.0	N/A	N/A	12.0	23.0	10.6	23.0
LTE Band 41 (PC2)	N/A	N/A	11.5	23.4	11.9	22.4	N/A	N/A	12.0	23.9	10.6	24.4
LTE Band 41 (PC2) ULCA	N/A	N/A	11.5	23.4	11.9	22.4	N/A	N/A	12.0	23.9	10.6	24.4
LTE Band 48	9.7	18.4	N/A	N/A	9.9	15.7	9.7	16.6	N/A	N/A	9.9	16.9
LTE Band 48 ULCA	9.7	18.4	N/A	N/A	9.9	15.7	9.7	16.6	N/A	N/A	9.9	16.9
NR Band n71	N/A	N/A	N/A	N/A	20.20	24.00	N/A	N/A	N/A	N/A	20.00	25.00
NR Band n12	N/A	N/A	N/A	N/A	19.30	24.00	N/A	N/A	N/A	N/A	19.10	25.00
NR Band n14	N/A	N/A	N/A	N/A	19.20	24.00	N/A	N/A	N/A	N/A	20.80	25.00
NR Band n26	N/A	N/A	N/A	N/A	18.80	24.00	N/A	N/A	N/A	N/A	19.00	25.00
NR Band n5	N/A	N/A	N/A	N/A	18.80	24.00	N/A	N/A	N/A	N/A	19.00	25.00
NR Band n70	N/A	N/A	12.00	25.00	14.50	24.50	N/A	N/A	12.50	24.50	14.60	25.00
NR Band n66	N/A	N/A	12.00	25.00	14.50	24.80	N/A	N/A	12.50	24.80	14.60	25.00
NR Band n2	N/A	N/A	10.90	22.00	14.60	23.00	N/A	N/A	12.00	24.00	13.70	25.00
NR Band n25	N/A	N/A	10.90	22.00	14.60	23.00	N/A	N/A	12.00	24.00	13.70	25.00
NR Band n30	N/A	N/A	12.30	21.50	13.00	20.05	N/A	N/A	12.10	21.80	14.50	25.00
NR Band n7	N/A	N/A	11.40	21.50	11.30	22.00	N/A	N/A	11.10	24.00	10.80	25.00
NR Band n41 (PC3)	N/A	N/A	12.00	25.00	12.00	25.00	N/A	N/A	11.80	25.00	10.50	25.00
NR Band n41 (PC2)	N/A	N/A	12.00	28.00	12.00	27.50	N/A	N/A	11.80	26.00	10.50	27.00
NR Band n77 (PC3)	9.20	22.30	N/A	N/A	8.30	22.30	8.40	24.70	N/A	N/A	9.60	24.70
NR Band n77 (PC2)	9.20	22.50	N/A	N/A	8.30	22.50	8.40	26.50	N/A	N/A	9.60	26.00
NR Band n48	9.70	20.40	N/A	N/A	9.90	17.70	10.00	18.60	N/A	N/A	10.00	18.90

Notes:

- *Maximum tune up output power Pmax is used to configure EUT during RF tune up procedure. The maximum allowed output power is equal to maximum Tune up output power +0.7/-1.0 dB conducted power tolerance and +1.0/-1.0 dB conducted power tolerance for UHB.
- All P_{limit} EFS and maximum tune up output power P_{max} levels entered in above Table correspond to average power levels after accounting for duty cycle in the case of TDD modulation schemes (for e.g., LTE TDD).

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For SAR measurements

Note:

1. CBT (Calibrated Before Testing): Prior to testing, the measurement paths containing a cable, amplifier, attenuator, coupler or filter were connected to a calibrated source (i.e. a signal generator) to determine the losses of the measurement path. The power meter offset was then adjusted to compensate for the measurement system losses. This level offset is stored within the power meter before measurements are made. This calibration verification procedure applies to the system verification and output power measurements. The calibrated reading is then taken directly from the power meter after compensation of the losses for all final power measurements.
2. Each equipment item was used solely within its respective calibration period.

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14 MEASUREMENT UNCERTAINTIES

For SAR Measurements

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	7	N	1	1	1	7.0	7.0	∞
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	∞
Modulation Response	E.2.5	4.8	R	1.732	1	1	2.8	2.8	∞
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	0.8	R	1.732	1	1	0.5	0.5	∞
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	3.12	N	1	1	1	3.1	3.1	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	4.3	N	1	0.78	0.71	3.3	3.0	76
Liquid Permittivity - measurement uncertainty	E.3.3	4.2	N	1	0.23	0.26	1.0	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 Uncertainty	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	12.2	12.0
Expanded Uncertainty (95% CONFIDENCE LEVEL)							k=2	24.4	24.0

The above measurement uncertainties are according to IEEE Std. 1528-2013

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