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Intertek
731 Enterprise Drive
Lexington, KY 40510

Tel 859 226 1000
Fax 859 226 1040

www.intertek.com

Akron Brass Company
SAR TEST REPORT

SCOPE OF WORK
SPECIFIC ABSORPTION RATE – SAM Nozzle

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SPECIFIC ABSORBTION RATE TEST REPORT

Report Number: 104917132LEX-003.3
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Report Issue Date: 6/30/2022
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Product Name: SAM Nozzle

Standards: FCC Part 2.1093
RSS-102 Issue 5
IEC/IEEE 62209-1528:2020

Tested by:
Intertek Testing Services NA, Inc.
731 Enterprise Drive
Lexington, KY 40510
USA

Client:
Akron Brass Company
343 Venture Blvd.
PO Box 86
Wooster, OH 44691-4681
USA

Report prepared by

Brian Lackey, Team Leader

Report reviewed by

James Sudduth, Senior Staff Engineer

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1 Introduction

At the request of Akron Brass Company the SAM Nozzle was evaluated for SAR in accordance with the requirements for FCC Part 2.1093, RSS-102 Issue 5, and IEC/IEEE 62209-1528. Testing was performed in accordance with IEEE Std 1528:2013, IEC62209-2:2010, IEC/IEEE 62209-1528, and the Office of Engineering and Technology KDB 447498. Testing was performed at the Intertek facility in Lexington, Kentucky.

For the evaluation, the dosimetric assessment system DASY52 was used. The total uncertainty for the evaluation of the spatial peak SAR values averaged over a cube of 1g tissue mass had been assessed for this system to be ±22.2% from 300MHz – 3GHz and 24.6% from 3GHz – 6GHz.

The SAM Nozzle was tested at the maximum output power measured by Intertek. Maximum output power measurements are tabulated in Section 8. The maximum spatial peak SAR values for the sample device averaged over 10-g and 1-g are shown below.

Based on the worst-case data presented below, the SAM Nozzle was found to be **compliant** with the requirements for general population / uncontrolled exposure.

Table 1: Worst Case Reported SAR per Exposure Condition

Device Position	Transmit Mode	Separation Distance	Channel	Conducted Output Power (dBm)	Reported 10-g SAR (W/kg)	10-g SAR Limit (W/kg)
Top	FHSS (single channel)	0mm	915MHz	29.63	0.652	4

Device Position	Transmit Mode	Separation Distance	Channel	Conducted Output Power (dBm)	Reported 1-g SAR (W/kg)	1-g SAR Limit (W/kg)
Top	FHSS (single channel)	0mm	915MHz	29.63	1.19	1.6

2 Test Site Description

The SAR test site located at 731 Enterprise Drive, Lexington KY 40510 is comprised of the SPEAG model DASY 5.2 automated near-field scanning system, which is a package, optimized for dosimetric evaluation of mobile radios [3]. This system is installed in an ambient-free shielded chamber. The ambient temperature is controlled to 22.0 $\pm 2^{o}$C. During the SAR evaluations, the RF ambient conditions are monitored continuously for signals that might interfere with the test results. The tissue simulating liquid is also stored in this area in order to keep it at the same constant ambient temperature as the room.

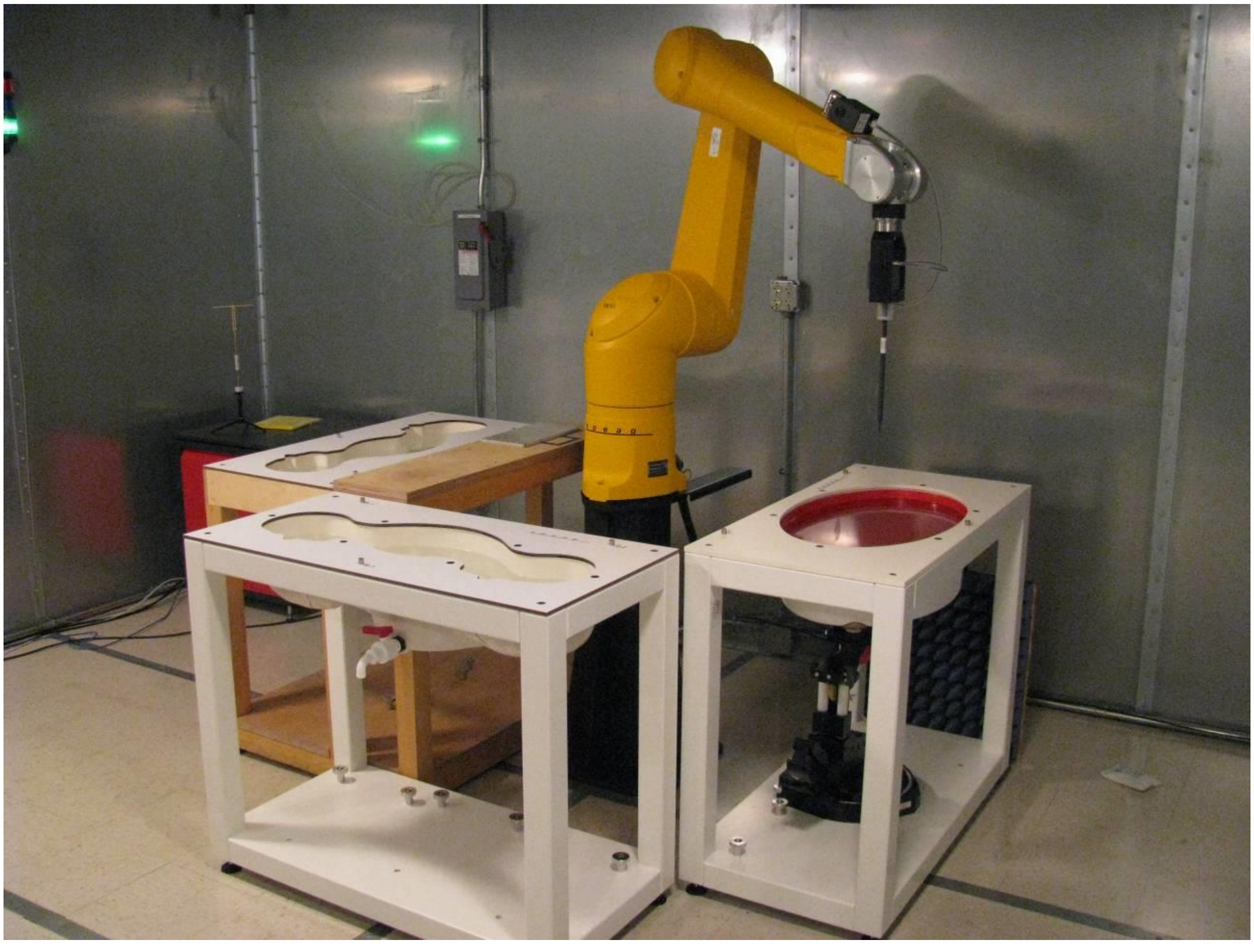


Figure 1: Intertek SAR Test Site

2.1 Measurement Equipment

The following major equipment/components were used for the SAR evaluation:

Table 2: Test Equipment Used for SAR Evaluation

Description	Asset Number	Manufacturer	Model	Cal. Date	Cal. Due
SAR Probe	3516	Speag	EXDV3	11/17/2022	11/17/2023
900MHz Dipole	3014	Speag	D900V2	11/11/2022	11/11/2023
DAE	3269	Speag	DAE4	11/10/2022	11/10/2023
Signal Generator	1015	HP	8656B	1/30/2023	1/30/2024
Network Analyzer	2538	Agilent	8753ES	4/5/2022	4/5/2023
Power Meter	2115	Boonton	5232	1/4/2023	1/4/2024
Power Sensor	3184	Boonton	51033-6E	11/23/2022	11/23/2023
Dielectric Probe Kit	3968	Speag	DAK-3.5	11/14/2022	11/14/2023
Spectrum Analyzer	3484	Rohde & Schwarz	FSQ	9/15/2022	9/15/2023
Oval Flat Phantom ELI 5.0	3620	Speag	QD OVA 002 A	NCR	NCR
6-axis robot	3608	Staubli	RX-90	NCR	NCR

**NCR – No Calibration Required*

2.2 Measurement Uncertainty

The Tables below includes the uncertainty budget suggested by the IEEE Std 1528-2013, IEC62209-2: 2010, and IEC/IEEE 62209-1528 as determined by SPEAG for the DASY5 measurement System.

Error Description	Uncertainty Value	Prob. Dist.	Div.	c_i (1g)	c_i (10g)	Std.Unc. (1g)	Std.Unc. (10g)	(v_i) v_{eff}
Measurement System								
Probe Calibration	±6.0%	N	1	1	1	±6.0%	±6.0%	∞
Axial Isotropy	±4.7%	R	√3	0.7	0.7	±1.9%	±1.9%	∞
Hemispherical Isotropy	±9.6%	R	√3	0.7	0.7	±3.9%	±3.9%	∞
Boundary Effect	±1.0%	R	√3	1	1	±0.6%	±0.6%	∞
Linearity	±4.7%	R	√3	1	1	±2.7%	±2.7%	∞
System Detection Limits	±1.0%	R	√3	1	1	±0.6%	±0.6%	∞
Modulation Response	±2.4%	R	√3	1	1	±1.4%	±1.4%	∞
Readout Electronics	±0.3%	N	1	1	1	±0.3%	±0.3%	∞
Response Time	±0.8%	R	√3	1	1	±0.5%	±0.5%	∞
Integration Time	±2.6%	R	√3	1	1	±1.5%	±1.5%	∞
RF Ambient Noise	±3.0%	R	√3	1	1	±1.7%	±1.7%	∞
RF Ambient Reflections	±3.0%	R	√3	1	1	±1.7%	±1.7%	∞
Probe Positioner	±0.4%	R	√3	1	1	±0.2%	±0.2%	∞
Probe Positioning	±2.9%	R	√3	1	1	±1.7%	±1.7%	∞
Max. SAR Eval.	±2.0%	R	√3	1	1	±1.2%	±1.2%	∞
Test sample Related								
Device Positioning	±2.9%	N	1	1	1	±2.9%	±2.9%	145
Device Holder	±3.6%	N	1	1	1	±3.6%	±3.6%	5
Power Drift	±5.0%	R	√3	1	1	±2.9%	±2.9%	∞
Power Scaling	±0.0%	R	√3	1	1	±0%	±0%	∞
Phantom and Setup								
Phantom Uncertainty	±6.1%	R	√3	1	1	±3.5%	±3.5%	∞
SAR Correction	±1.9%	R	√3	1	0.84	±1.1%	±0.9%	∞
Liquid Conductivity (mea.)	±2.5%	R	√3	0.78	0.71	±1.1%	±1.0%	∞
Liquid Permittivity (mea.)	±2.5%	R	√3	0.26	0.26	±0.3%	±0.4%	∞
Temp unc. - Conductivity	±3.4%	R	√3	0.78	0.71	±1.5%	±1.4%	∞
Temp unc. - Permittivity	±0.4%	R	√3	0.23	0.26	±0.1%	±0.1%	∞
Combined Standard Uncertainty						±11.2%	±11.1%	361
Expanded STD Uncertainty						**±22.3%**	**±22.2%**	

Notes:

Worst Case uncertainty budget for DASY5 assessed according to IEEE 1528-2013. The budget is valid for the frequency range 300 MHz – 3 GHz and represents a worst-case analysis. For specific tests and configurations, the uncertainty could be considerably smaller.

Error Description	Uncertainty Value	Prob. Dist.	Div.	c_i (1g)	c_i (10g)	Std.Unc. (1g)	Std.Unc. (10g)	(v_i) v_{eff}
Measurement System								
Probe Calibration	±6.55%	N	1	1	1	±6.55%	±6.55%	∞
Axial Isotropy	±4.7%	R	√3	0.7	0.7	±1.9%	±1.9%	∞
Hemispherical Isotropy	±9.6%	R	√3	0.7	0.7	±3.9%	±3.9%	∞
Boundary Effect	±2.0%	R	√3	1	1	±1.2%	±1.2%	∞
Linearity	±4.7%	R	√3	1	1	±2.7%	±2.7%	∞
System Detection Limits	±1.0%	R	√3	1	1	±0.6%	±0.6%	∞
Modulation Response	±2.4%	R	√3	1	1	±1.4%	±1.4%	∞
Readout Electronics	±0.3%	N	1	1	1	±0.3%	±0.3%	∞
Response Time	±0.8%	R	√3	1	1	±0.5%	±0.5%	∞
Integration Time	±2.6%	R	√3	1	1	±1.5%	±1.5%	∞
RF Ambient Noise	±3.0%	R	√3	1	1	±1.7%	±1.7%	∞
RF Ambient Reflections	±3.0%	R	√3	1	1	±1.7%	±1.7%	∞
Probe Positioner	±0.8%	R	√3	1	1	±0.5%	±0.5%	∞
Probe Positioning	±6.7%	R	√3	1	1	±3.9%	±3.9%	∞
Max. SAR Eval.	±4.0%	R	√3	1	1	±2.3%	±2.3%	∞
Test sample Related								
Device Positioning	±2.9%	N	1	1	1	±2.9%	±2.9%	145
Device Holder	±3.6%	N	1	1	1	±3.6%	±3.6%	5
Power Drift	±5.0%	R	√3	1	1	±2.9%	±2.9%	∞
Power Scaling	±0.0%	R	√3	1	1	±0%	±0%	∞
Phantom and Setup								
Phantom Uncertainty	±6.6%	R	√3	1	1	±3.8%	±3.8%	∞
SAR Correction	±1.9%	R	√3	1	0.84	±1.1%	±0.9%	∞
Liquid Conductivity (mea.)	±2.5%	R	√3	0.78	0.71	±1.1%	±1.0%	∞
Liquid Permittivity(mea.)	±2.5%	R	√3	0.26	0.26	±0.3%	±0.4%	∞
Temp unc. - Conductivity	±3.4%	R	√3	0.78	0.71	±1.5%	±1.4%	∞
Temp unc. - Permittivity	±0.4%	R	√3	0.23	0.26	±0.1%	±0.1%	∞
Combined Standard Uncertainty						±12.3%	±12.2%	748
Expanded STD Uncertainty						**±24.6%**	**±24.5%**	

Notes:

Worst Case uncertainty budget for DASY5 assessed according to IEEE 1528-2013 and IEC/IEEE 62209-1528. The budget is valid for the frequency range 3 GHz – 6 GHz and represents a worst-case analysis. Probe calibration error reflects uncertainty of the EX3D probe. For specific tests and configurations, the uncertainty could be considerably smaller.

Error Description	Uncertainty Value	Prob. Dist.	Div.	c_i (1g)	c_i (10g)	Std.Unc. (1g)	Std.Unc. (10g)	(v_i) v_{eff}
Measurement System								
Probe Calibration	±6.55%	N	1	1	1	±6.55%	±6.55%	∞
Axial Isotropy	±4.7%	R	√3	0.7	0.7	±1.9%	±1.9%	∞
Hemispherical Isotropy	±9.6%	R	√3	0.7	0.7	±3.9%	±3.9%	∞
Boundary Effect	±2.0%	R	√3	1	1	±1.2%	±1.2%	∞
Linearity	±4.7%	R	√3	1	1	±2.7%	±2.7%	∞
System Detection Limits	±1.0%	R	√3	1	1	±0.6%	±0.6%	∞
Modulation Response	±2.4%	R	√3	1	1	±1.4%	±1.4%	∞
Readout Electronics	±0.3%	N	1	1	1	±0.3%	±0.3%	∞
Response Time	±0.8%	R	√3	1	1	±0.5%	±0.5%	∞
Integration Time	±2.6%	R	√3	1	1	±1.5%	±1.5%	∞
RF Ambient Noise	±3.0%	R	√3	1	1	±1.7%	±1.7%	∞
RF Ambient Reflections	±3.0%	R	√3	1	1	±1.7%	±1.7%	∞
Probe Positioner	±0.8%	R	√3	1	1	±0.5%	±0.5%	∞
Probe Positioning	±6.7%	R	√3	1	1	±3.9%	±3.9%	∞
Post-Processing	±4.0%	R	√3	1	1	±2.3%	±2.3%	∞
Test sample Related								
Device Positioning	±2.9%	N	1	1	1	±2.9%	±2.9%	145
Device Holder	±3.6%	N	1	1	1	±3.6%	±3.6%	5
Power Drift	±5.0%	R	√3	1	1	±2.9%	±2.9%	∞
Power Scaling	±0.0%	R	√3	1	1	±0%	±0%	∞
Phantom and Setup								
Phantom Uncertainty	±7.9%	R	√3	1	1	±4.6%	±4.6%	∞
SAR Correction	±1.9%	R	√3	1	0.84	±1.1%	±0.9%	∞
Liquid Conductivity (mea.)	±2.5%	R	√3	0.78	0.71	±1.1%	±1.0%	∞
Liquid Permittivity (mea.)	±2.5%	R	√3	0.26	0.26	±0.3%	±0.4%	∞
Temp unc. - Conductivity	±3.4%	R	√3	0.78	0.71	±1.5%	±1.4%	∞
Temp unc. - Permittivity	±0.4%	R	√3	0.23	0.26	±0.1%	±0.1%	∞
Combined Standard Uncertainty						±12.5%	±12.5%	748
Expanded STD Uncertainty						**±25.1%**	**±25.0%**	

Notes:

Worst Case uncertainty budget for DASY5 assessed according to IEC62209-2: 2010 and IEC/IEEE 62209-1528. The budget is valid for the frequency range 30MHz – 6 GHz and represents a worst-case analysis. Probe calibration error reflects uncertainty of the EX3D probe. For specific tests and configurations, the uncertainty could be considerably smaller.

3 Description of Equipment under Test

Equipment Under Test	
Product Name	SAM Nozzle
Model Number	6055
Serial Number	Unit 1
Embedded Module	Digi XBee-PRO SX
Supported Transmit Modes	FHSS, 110kbps, 250kHz channel spacing, GFSK
Embedded Module FCCID / ICID	FCCID: MCQ-XBPSX, ICID: 1846A-XBPSX
Test Channels	915 MHz, 921.25 MHz, 927.25 MHz
Embedded Module	Espressif ESP-WROOM-02D[1]
Supported Transmit Modes	802.11b/g/n
Embedded Module FCCID / ICID	FCCID: 2AC7Z-ESPWROOM02D, ICID: 21098-ESPWRO
Receive Date	6/16/2022
Test Start Date	6/16/2022
Test End Date	2/8/2023
Device Received Condition	Good
Test Sample Type	Production
Rated Voltage	3.7VDC (Battery)
Antenna Gains[2]	-7.3dBi

Description of Equipment Under Test[2]

The SAM Smart Nozzle is an industry-first product that serves as part of the SAM Advanced Flow System (AFS). It provides firefighters with enhanced situational awareness capability and aids in automating the firefighting process. This is accomplished via the following functionality:

- The ability to open the valve and charge the fire hose from the nozzle;
- Provision of water status information to the nozzle operator;
- Provision of local pressure sensor measurements from the nozzle to the SAM system to account for friction loss.

Operating Band	Technology	Modulation	Frequency Range (MHz)	Maximum Output Power (dBm)	Duty Cycle
902 – 928 MHz	FHSS	GFSK, 110kbps	902.5 – 927.5 MHz	30	1:1

[1] The ESP-WROOM-02D radio is used once for initial configuration and disabled for the remainder of the product service life. The ESP-WROOM-02D is not subject to SAR evaluation as the radio is never enabled when the EUT is in its normal operating mode.

[2] This information was provided by the client and may affect compliance. Intertek makes no claims of compliance for any device(s) other than those identified herein. Intertek cannot attest to the accuracy of any client-provided data.

3.1 Duty Cycle Correction Factor Derivation

The following measurements were performed by the client. Deviations from these values may affect compliance. Intertek does not make any claim of compliance for values other than those shown below.

A series of current draw measurements were taken on a prototype 6055 SAM Smart Nozzle unit while it was responding to poll requests every 100 ms. A series of traces showing the captured time deltas for TX ON and TX OFF are provided. The resulting measurements show a cumulative TX time of 17.4 ms for every 100 ms polling period. Consequently, the reported SAR values for the unit being tested can be multiplied by 17.4% per KDB 447498 D04 Interim General RF Exposure Guidance v01 § 5.3.

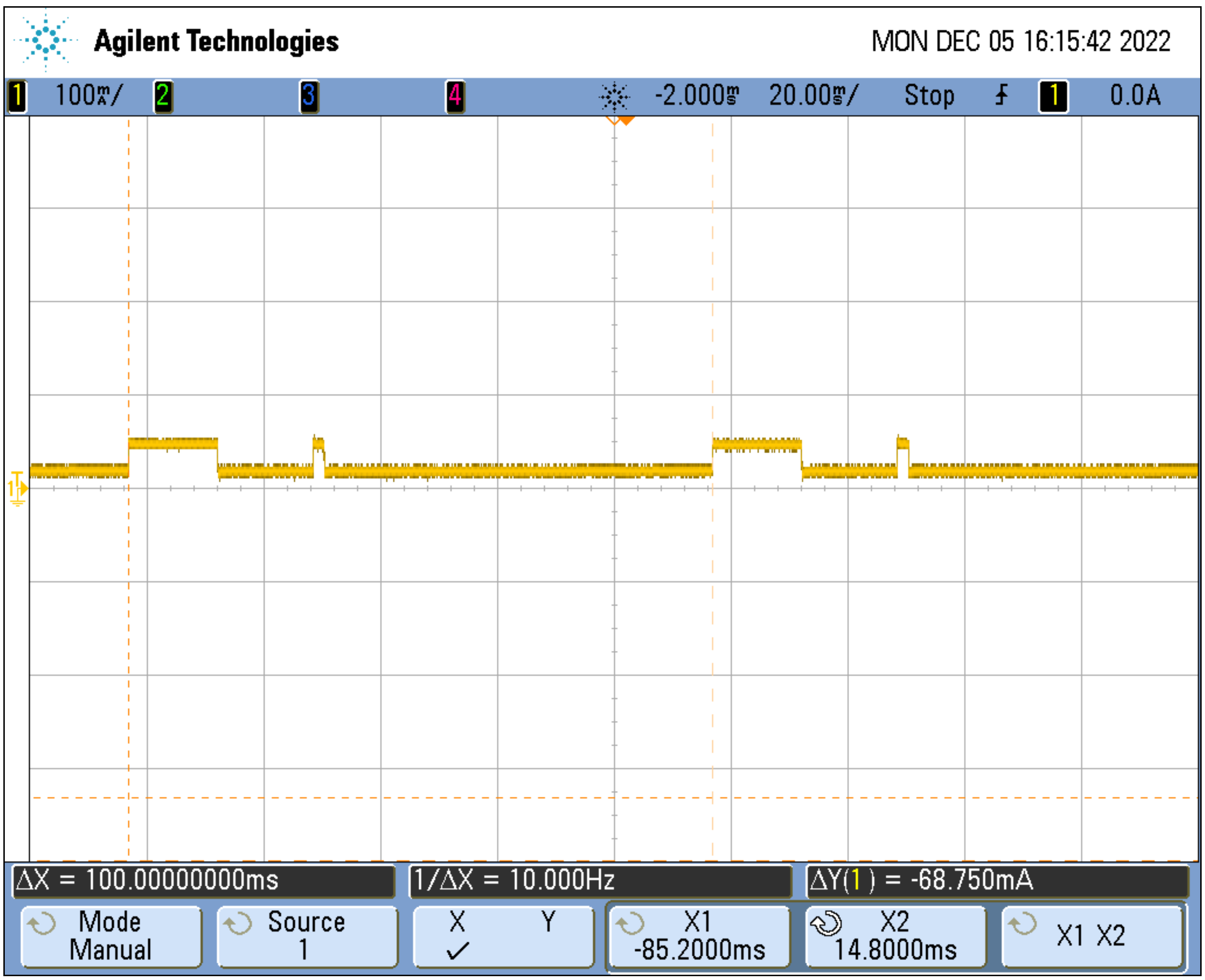


Figure 2 – Measured Time Between Pulses = 100ms

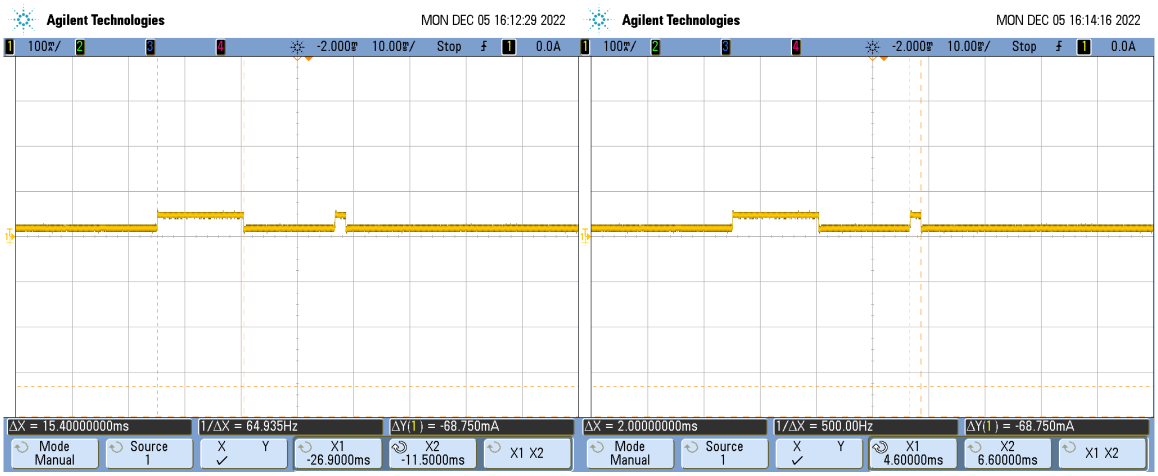


Figure 3 – Accumulated Transmit Time of 15.4ms (left) and 2ms (right) = 17.4ms

The equipment used for taking these measurements included an Agilent InfiniVision MSO7034A oscilloscope with an Agilent N2774A current probe, which received power from an Agilent N2775A power supply.

4 System Verification
4.1 System Validation

Prior to the assessment, the system was verified to be within ±10% of the specifications by using the system validation kit. The system validation procedure tests the system against reference SAR values and the performance of probe, readout electronics and software. The test setup utilizes a phantom and reference dipole.

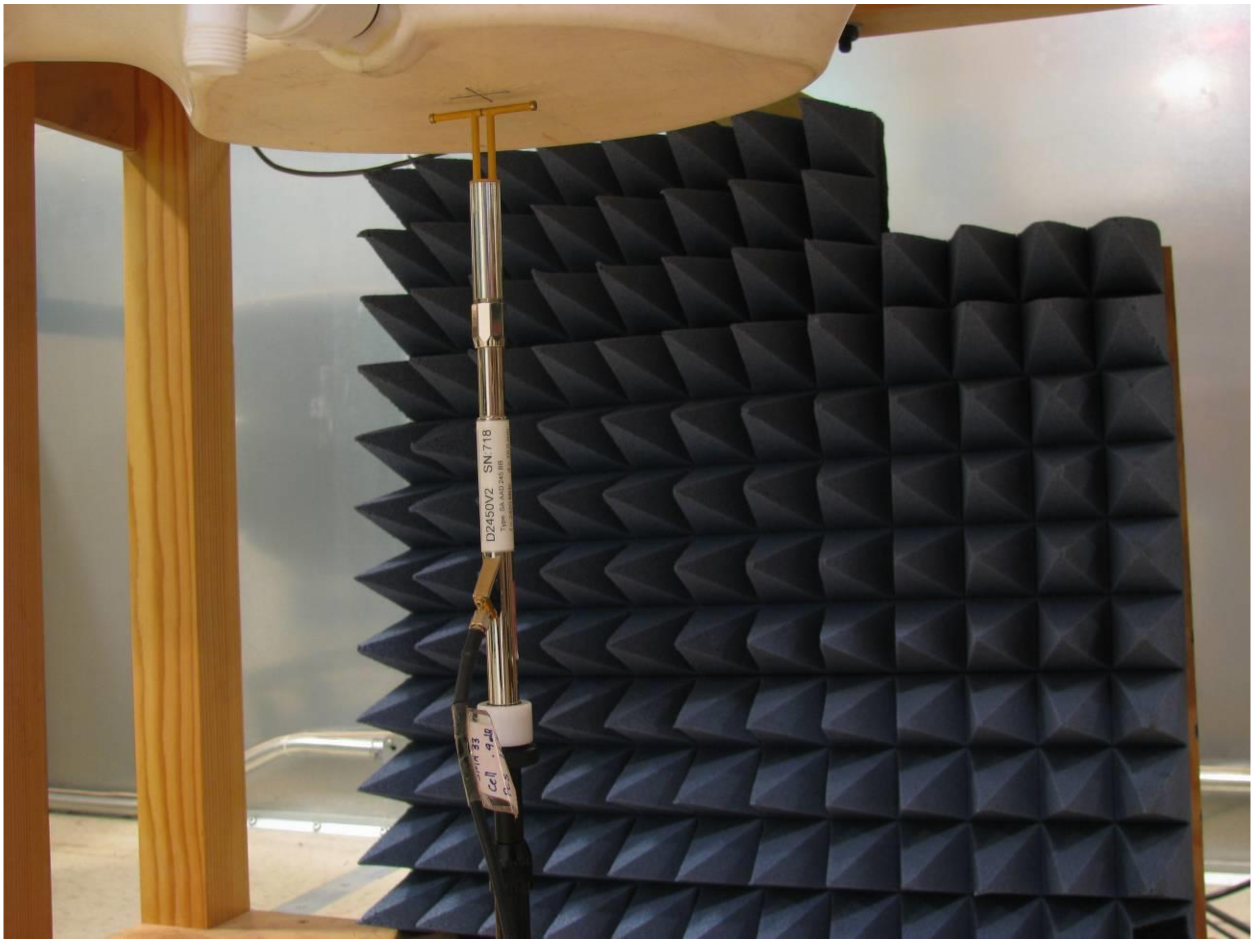


Figure 4: System Verification Setup

Table 3: Dipole Validations

Reference Dipole Validation									
Ambient Temp (ºC)	Fluid Temp (ºC)	Frequency (MHz)	Dipole	Fluid Type	Dipole Power Input	Cal. Lab SAR (1g)	Measured SAR (1g)	% Error SAR (1g)	Date
23.2	23.1	900MHz	D900V2	900MSL	1W	11.20	11.50	2.68	2/7/2023

Reference Dipole Validation									
Ambient Temp (ºC)	Fluid Temp (ºC)	Frequency (MHz)	Dipole	Fluid Type	Dipole Power Input	Cal. Lab SAR (10g)	Measured SAR (10g)	% Error SAR (10g)	Date
22	22	900MHz	D900V2	900MSL	1W	7.24	7.52	3.87	2/7/2023

4.2 Measurement Uncertainty for System Validation

Source of Uncertainty	Value(dB)	Probability Distribution	Divisor	c_i	$u_i(y)$	$(u_i(y))^2$
Measurement System						
Probe Calibration	5.50	n1	1	1	5.50	30.250
Axial Isotropy	4.70	r	1.732	0.7	2.71	7.364
Hemispherical Isotropy	9.60	r	1.732	0.7	5.54	30.722
Boundary Effect	1.00	r	1.732	1	0.58	0.333
Linearity	4.70	r	1.732	1	2.71	7.364
System Detection Limits	1.00	r	1.732	1	0.58	0.333
Readout Electronics	0.30	n1	1	1	0.30	0.090
Response Time	0.80	r	1.732	1	0.46	0.213
Integration Time	2.60	r	1.732	1	1.50	2.253
RF Ambient Noise	3.00	r	1.732	1	1.73	3.000
RF Ambient Reflections	3.00	r	1.732	1	1.73	3.000
Probe Positioner	0.40	r	1.732	1	0.23	0.053
Probe Positioning	2.90	r	1.732	1	1.67	2.803
Max. SAR Eval.	1.00	r	1.732	1	0.58	0.333
Dipole / Generator / Power Meter Related						
Dipole positioning	2.90	n1	1	1	2.90	8.410
Dipole Calibration Uncertainty	0.68	r	1.732	1	0.39	0.154
Power Meter 1 Uncertainty (+20C to +25C)	0.13	n1	1	2	0.13	0.017
Power Meter 2 Uncertainty (+20C to +25C)	0.04	n1	1	3	0.04	0.002
Sig Gen VSWR Mismatch Error	1.80	n1	1	5	1.80	3.240
Sig Gen Resolution Error	0.01	n1	1	6	0.01	0.000
Sig Gen Level Error	0.90	n1	1	1	0.90	0.810
Phantom and Setup						
Phantom Uncertainty	4.00	r	1.732	1	2.31	5.334
Liquid Conductivity (target)	5.00	r	1.732	0.43	2.89	8.334
Liquid Conductivity (meas.)	2.50	n1	1	0.43	2.50	6.250
Liquid Permittivity (target)	5.00	r	1.732	0.49	2.89	8.334
Liquid Permittivity (meas.)	2.50	n1	1	0.49	2.50	6.250
Combined Standard Uncertainty		N1	1	1	11.63	135.247
Expanded Uncertainty		Normal k=	2		**23.26**	

4.3 Tissue Simulating Liquid Description and Validation

The dielectric parameters were verified to be within 5% of the target values prior to assessment. The dielectric parameters (ε_r, σ) are shown in Table 4. A recipe for the tissue simulating fluid used is shown in Table 5.

Table 4: Dielectric Parameter Validations

Tissue Type	Frequency Measure (MHz)	Dielectric Constant Target	Conductivity Target	Dielectric Constant Measure	Imaginary Part	Conductivity Measure	Dielectric % Deviation	Conductivity % Deviation	Date
915MHz MSL	915	55	1.06	55.4	21.41	1.09	0.65	2.83	2/7/2023

Table 5: Tissue Simulating Fluid Recipe

Composition of Ingredients for Liquid Tissue Phantoms (450MHz to 2450 MHz data only)												
Ingredient (% by weight)	**f (MHz)**											
	450		**835**		**915**		**1900**		**2450**		**5500**	
Tissue Type	**Head**	**Body**	**Head**	**Body**	**Head**	**Body**	**Head**	**Body**	**Head**	**Body**	**Head**	**Body**
Water	38.56	51.16	41.45	52.4	41.05	56	54.9	70.45	62.7	68.64	65.53	78.67
Salt (NaCl)	3.95	1.49	1.45	1.4	1.35	0.76	0.18	0.36	0.5			
Sugar	56.32	46.78	56	45	56.5	41.76						
HEC	0.98	0.52	1	1	1	1.21						
Bactericide	0.19	0.05	0.1	0.1	0.1	0.27						
Triton X-100									36.8		17.235	10.665
DGBE							44.92	29.18		31.37		
DGHE											17.235	10.665
Dielectric Constant	43.42	58	42.54	56.1	42	56.8	39.9	53.3	39.8	52.7		
Conductivity (S/m)	0.85	0.83	0.91	0.95	1	1.07	1.42	1.52	1.88	1.95		

Tissue Simulating Liquid for 5GHz, MBBL3500-5800V5 Manufactured by SPEAG (proprietary mixture)

Ingredients	**(% by weight)**
Water	78
Mineral oil	11
Emulsifiers	9
Additives and Salt	2

5 Evaluation Procedures

Prior to any testing, the appropriate fluid was used to fill the phantom to a depth of 15 cm ±0.2cm. The fluid parameters were verified and the dipole validation was performed as described in the previous sections.

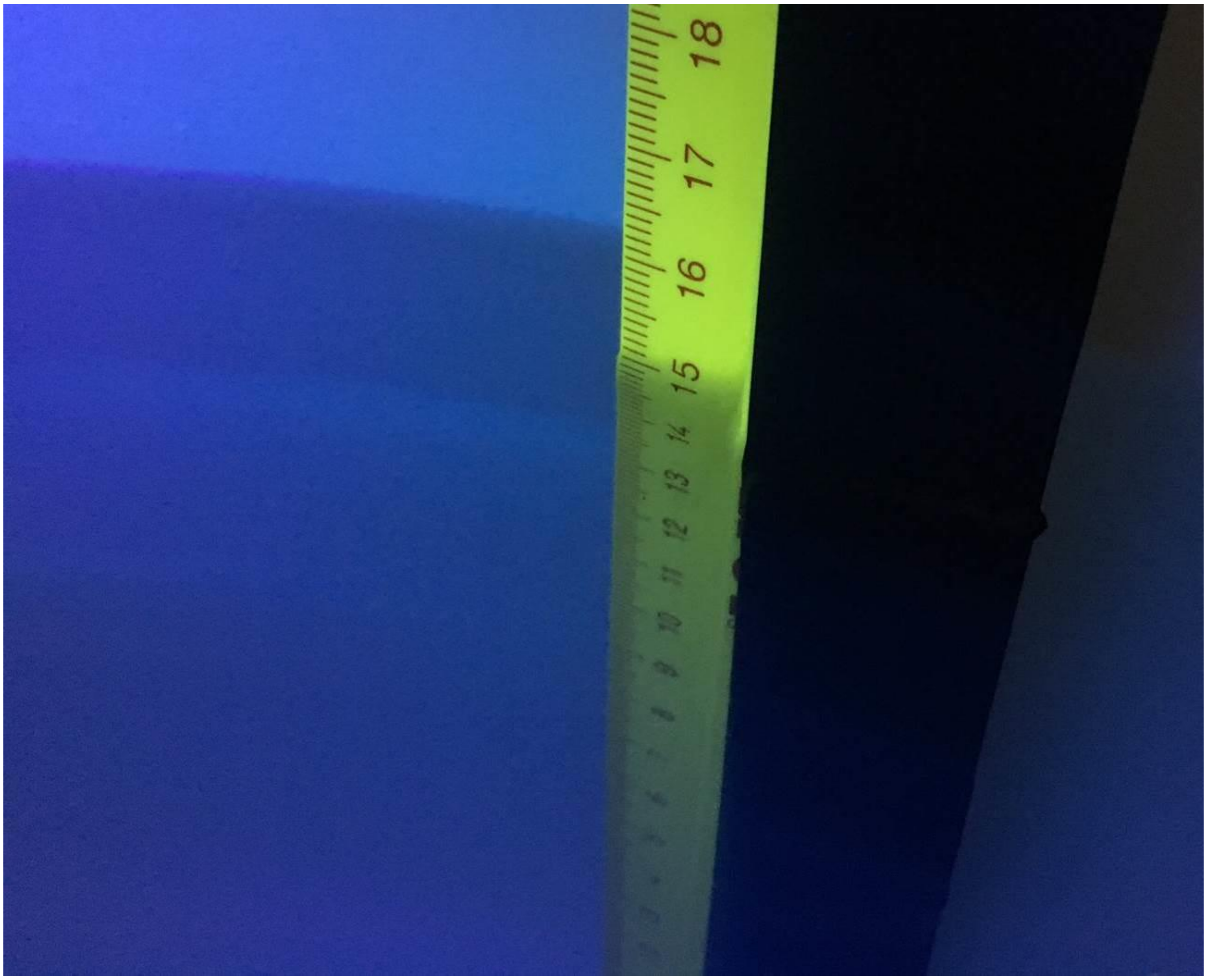


Figure 5: Fluid Depth 15cm

5.1 Test Positions:

The Device was positioned against the flat phantom using the exact procedure described in IEEE Std 1528:2013, IEC62209-2:2010, IEC/IEEE 62209-1528, and the Office of Engineering and Technology KDB 447498. Due to physical constraints and the shape of the SAM Nozzle the bottom, front, and back sides of the device could not be tested against the phantom.

5.2 Reference Power Measurement:

The measurement probe was positioned at a fixed location above the reference point. A power measurement was made with the probe above this reference position so it could used for the assessing the power drift later in the test procedure.

5.3 Area Scan:

A coarse area scan was performed in order to find the approximate location of the peak SAR value. This scan was performed with the measurement probe at a constant height in the simulating fluid. A two dimensional spline interpolation algorithm was then used to determine the peaks and gradients within the scanned area. The area scan resolution conformed to the requirements of KDB 865664 as shown in Table 6.

5.4 Zoom Scan:

A zoom scan was performed around the approximate location of the peak SAR as determined from the area scan. On the basis of this data set, the spatial peak SAR value was evaluated with the following procedure. The zoom scan resolution conformed to the requirements of KDB 865664 as shown in Table 6.

Table 6: SAR Area and Zoom Scan Resolutions

			≤ 3 GHz	> 3 GHz
Maximum distance from closest measurement point (geometric center of probe sensors) to phantom surface			5 ± 1 mm	$\frac{1}{2} \cdot \delta \cdot \ln(2) \pm 0.5$ mm
Maximum probe angle from probe axis to phantom surface normal at the measurement location			30° ± 1°	20° ± 1°
Maximum area scan spatial resolution: Δx_{Area}, Δy_{Area}			≤ 2 GHz: ≤ 15 mm 2 – 3 GHz: ≤ 12 mm	3 – 4 GHz: ≤ 12 mm 4 – 6 GHz: ≤ 10 mm
			When the x or y dimension of the test device, in the measurement plane orientation, is smaller than the above, the measurement resolution must be ≤ the corresponding x or y dimension of the test device with at least one measurement point on the test device.	
Maximum zoom scan spatial resolution: Δx_{Zoom}, Δy_{Zoom}			≤ 2 GHz: ≤ 8 mm 2 – 3 GHz: ≤ 5 mm*	3 – 4 GHz: ≤ 5 mm* 4 – 6 GHz: ≤ 4 mm*
Maximum zoom scan spatial resolution, normal to phantom surface	uniform grid: $\Delta z_{Zoom}(n)$		≤ 5 mm	3 – 4 GHz: ≤ 4 mm 4 – 5 GHz: ≤ 3 mm 5 – 6 GHz: ≤ 2 mm
	graded grid	$\Delta z_{Zoom}(1)$: between 1st two points closest to phantom surface	≤ 4 mm	3 – 4 GHz: ≤ 3 mm 4 – 5 GHz: ≤ 2.5 mm 5 – 6 GHz: ≤ 2 mm
		$\Delta z_{Zoom}(n>1)$: between subsequent points	$\leq 1.5 \cdot \Delta z_{Zoom}(n-1)$	
Minimum zoom scan volume	x, y, z		≥ 30 mm	3 – 4 GHz: ≥ 28 mm 4 – 5 GHz: ≥ 25 mm 5 – 6 GHz: ≥ 22 mm

Note: δ is the penetration depth of a plane-wave at normal incidence to the tissue medium; see draft standard IEEE P1528-2011 for details.

* When zoom scan is required and the *reported* SAR from the *area scan based 1-g SAR estimation* procedures of KDB 447498 is ≤ 1.4 W/kg, ≤ 8 mm, ≤ 7 mm and ≤ 5 mm zoom scan resolution may be applied, respectively, for 2 GHz to 3 GHz, 3 GHz to 4 GHz and 4 GHz to 6 GHz.

5.5 Interpolation, Extrapolation and Detection of Maxima:

The probe is calibrated at the center of the dipole sensors which is located 1 to 2.7 mm away from the probe tip. During measurements, the probe stops shortly above the phantom surface, depending on the probe and the surface detecting system. Both distances are included as parameters in the probe configuration file. The software always knows exactly how far away the measured point is from the surface. As the probe cannot directly measure at the surface, the values between the deepest measured point and the surface must be extrapolated.

In DASY5, the choice of the coordinate system defining the location of the measurement points has no influence on the uncertainty of the interpolation, Maxima Search and extrapolation routines. The interpolation, extrapolation and maximum search routines are all based on the modified Quadratic Shepard's method.

Thereby, the interpolation scheme combines a least-square fitted function method and a weighted average method which are the two basic types of computational interpolation and approximation. The DASY5 routines construct a once-continuously differentiable function that interpolates the measurement values as follows:

- For each measurement point a trivariate (3-D) / bivariate (2-D) quadratic is computed. It interpolates the measurement values at the data point and forms a least-square fit to neighboring measurement values.
- The spatial location of the quadratic with respect to the measurement values is attenuated by an inverse distance weighting. This is performed since the calculated quadratic will fit measurement values at nearby points more accurate than at points located further away.
- After the quadratics are calculated for at all measurement points, the interpolating function is calculated as a weighted average of the quadratics.

There are two control parameters that govern the behavior of the interpolation method. One specifies the number of measurement points to be used in computing the least-square fits for the local quadratics. These measurement points are the ones nearest the input point for which the quadratic is being computed. The second parameter specifies the number of measurement points that will be used in calculating the weights for the quadratics to produce the final function. The input data points used there are the ones nearest the point at which the interpolation is desired. Appropriate defaults are chosen for each of the control parameters.

The trivariate quadratics that have been previously computed for the 3-D interpolation and whose input data are at the closest distance from the phantom surface, are used in order to extrapolate the fields to the surface of the phantom.

In order to determine all the field maxima in 2-D (Area Scan) and 3-D (Zoom Scan), the measurement grid is refined by a default factor of 10 and the interpolation function is used to evaluate all field values between corresponding measurement points. Subsequently, a linear search is applied to find all the candidate maxima. In a last step, non-physical maxima are removed and only those maxima which are within 2 dB of the global maximum value are retained.

5.6 Averaging and Determination of Spatial Peak SAR

The interpolated data is used to average the SAR over the 1g and 10g cubes by spatially discretizing the entire measured volume. The resolution of this spatial grid used to calculate the averaged SAR is 1mm or about 42875 interpolated points. The resulting volumes are defined as cubical volumes containing the appropriate tissue parameters that are centered at the location. The location is defined as the center of the incremental volume.

The spatial-peak SAR must be evaluated in cubical volumes containing a mass that is within 5% of the required mass. The cubical volume centered at each location, as defined above, should be expanded in all directions until the desired value for the mass is reached, with no surface boundaries of the averaging volume extending beyond the outermost surface of the considered region. In addition, the cubical volume should not consist of more than 10% of air. If these conditions are not satisfied then the center of the averaging volume is moved to the next location. Otherwise, the exact size of the final sampling cube is found using an inverse polynomial approximation algorithm, leading to results with improved accuracy. If one boundary of the averaging volume reaches the boundary of the measured volume during its expansion, it will not be evaluated at all. Reference is kept of all locations used and those not used for averaging the SAR. All average SAR values are finally assigned to the centered location in each valid averaging volume.

All locations included in an averaging volume are marked to indicate that they have been used at least once. If a location has been marked as used, but has never been assigned to the center of a cube, the highest averaged SAR value of all other cubical volumes which have used this location for averaging is assigned to this location. Only those locations that are not part of any valid averaging volume should be marked as unused. For the case of an unused location, a new averaging volume must be constructed which will have the unused location centered at one surface of the cube. The remaining five surfaces are expanded evenly in all directions until the required mass is enclosed, regardless of the amount of included air. Of the six possible cubes with one surface centered on the unused location, the smallest cube is used, which still contains the required mass.

If the final cube containing the highest averaged SAR touches the surface of the measured volume, an appropriate warning is issued within the post processing engine.

5.7 Power Drift Measurement:

The probe was positioned at precisely the same reference point and the reference power measurement was repeated. The difference between the initial reference power and the final one is referred to as the power drift. This value should not exceed 5%. The power drift measurement was used to assess the output power stability of the test sample throughout the SAR scan.

5.8 RF Ambient Activity:

During the entire SAR evaluation, the RF ambient activity was monitored using a spectrum analyzer with an antenna connected to it. The spectrum analyzer was tuned to the frequency of measurement and with one trace set to max hold mode. In this way, it was possible to determine if at any point during the SAR measurement there was an interfering ambient signal. If an ambient signal was detected, then the SAR measurement was repeated.

6 Criteria

The following ANSI/IEEE C95.1 – 1992 limits for SAR apply to portable devices operating in the General Population / Uncontrolled Exposure environment.

Exposure Type (General Population/Uncontrolled Exposure environment)	**SAR Limit (W/kg or mW/g)**
Average over the whole body	0.08
Spatial Peak (1g)	1.6
Spatial Peak for hands, wrists, feet and ankles (10g)	4

7 Test Configuration

The SAM Nozzle was designed to be used in the operator's hands, near the body. Therefore, the EUT was placed against the phantom to simulate extremity and body operation. Due to physical constraints and the shape of the SAM Nozzle the bottom, front, and back sides of the device could not be tested against the phantom.

The device was evaluated according to the specific requirements found in the following KDBs and Standards:

- FCC KDB 447498D01 v06, General RF Exposure Guidance
- FCC KDB 865664D01 v01r04, SAR Measurement Requirements for 100MHz to 6GHz
- RSS-102 Issue 5, Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)
- IEC/IEEE 62209-1528

8 Test Results

The worst case scaled 10-g SAR value for extremity exposure was less than the 4W/kg limit. The worst case scaled 1-g SAR value for body exposure was less than the 1.6W/kg limit.

9 SAR Data:

The following results were obtained when the device was transmitting at maximum output power. The worst case plots, which reveal information about the location of the maximum SAR with respect to the device, are referenced are shown in APPENDIX B – Worst Case SAR Plot. The measured conducted output power was compared to the power declared by the manufacturer and used for scaling the measured SAR values. The duty cycle correction factor was applied to the reported SAR values.

Table 7: SAR Results

900MHz Band 10-g Body SAR Results								
Date	Channel	Position	Power Drift (dB)	Measured Output Power (dBm)	Maximum Output Power (dBm)	Measured 10-g SAR (W/kg)	Reported 10-g SAR (W/kg)	Scaled 10-g SAR (W/kg)
2/8/2023	Low (915 MHz)	**Top**	**-0.01**	**29.63**	**30.00**	**3.44E+00**	**3.75E+00**	**6.52E-01**
		Top	-0.02	29.63	30.00	3.11E+00	3.39E+00	5.89E-01
		Left	0.03	29.63	30.00	1.70E-02	1.85E-02	3.22E-03
		Right	-0.01	29.63	30.00	2.68E-02	2.92E-02	5.08E-03
2/8/2023	Mid (921.25 MHz)	Top	-0.01	29.04	30.00	2.85E+00	3.56E+00	6.19E-01
2/8/2023	High (927.25 MHz)	Top	-0.04	28.94	30.00	2.45E+00	3.13E+00	5.44E-01

900MHz Band 1-g Body SAR Results								
Date	Channel	Position	Power Drift (dB)	Measured Output Power (dBm)	Maximum Output Power (dBm)	Measured 1-g SAR (W/kg)	Reported 1-g SAR (W/kg)	Scaled 1-g SAR (W/kg)
2/8/2023	Low (915 MHz)	**Top**	**-0.01**	**29.63**	**30.00**	**6.26E+00**	**6.82E+00**	**1.19E+00**
		Top	-0.02	29.63	30.00	5.53E+00	6.02E+00	1.05E+00
		Left	0.03	29.63	30.00	2.70E-02	2.94E-02	5.12E-03
		Right	-0.01	29.63	30.00	4.01E-02	4.37E-02	7.60E-03
2/8/2023	Mid (921.25 MHz)	Top	-0.01	29.04	30.00	5.15E+00	6.42E+00	1.12E+00
2/8/2023	High (927.25 MHz)	Top	-0.04	28.94	30.00	4.45E+00	5.68E+00	9.88E-01

Test Personnel:	Brian Lackey	Test Date:	2/8/2023
Supervising/Reviewing Engineer: (Where Applicable)	NA	Tissue Depth:	15cm
Signal Setup:	Test Commands	Ambient Temperature:	22.4C
Power Method:	Fully Charged Battery	Relative Humidity:	48.6%
Pretest Dipole Verification:	Yes	Atmospheric Pressure:	989.2mbar

Deviations, Additions, or Exclusions: The measurement on the top position was repeated per FCC KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz v01r04 clause 2.8.1.

10 APPENDIX A – System Validation Summary

Per FCC KDB 865664, a tabulated summary of the system validation status including the validation date(s), measurement frequencies, SAR probes and tissue dielectric parameters have been included in the summary table below. The validation was performed with reference dipoles using the required tissue equivalent media for system validation according to KDB 865664. Each probe calibration point was validated at a frequency within the valid frequency range of the probe calibration point. All measurements were performed using probes calibrated for CW signals. Modulations in the table above represent test configurations for which the SAR system has been validated. The SAR system was also validated with modulated signals per KDB 865664.

Table 8: SAR System Validation Summary

				Probe Calibration Point		Dielectric Properties		CW Validation			Modulation Validation		
Frequency (MHz)	Date	Probe (SN#)	Probe (Model #)	Frequency (MHz)	Fluid Type	σ	ϵ_r	Sensitivity	Probe Linearity	Probe Isotropy	Mod. Type	Duty Factor	PAR
2450	2/7/2023	3516	EX3DV3	2450	Body	50.65	2.02	Pass	Pass	Pass	OFDM	N/A	Pass
5200	2/7/2023	3516	EX3DV3	5200	Body	48.71	5.54	Pass	Pass	Pass	OFDM	N/A	Pass
5500	2/7/2023	3516	EX3DV3	5500	Body	47.68	6.29	Pass	Pass	Pass	OFDM	N/A	Pass
5800	2/7/2023	3516	EX3DV3	5800	Body	48.71	5.54	Pass	Pass	Pass	OFDM	N/A	Pass

				Probe Calibration Point		Dielectric Properties		CW Validation			Modulation Validation		
Frequency (MHz)	Date	Probe (SN#)	Probe (Model #)	Frequency (MHz)	Fluid Type	σ	ϵ_r	Sensitivity	Probe Linearity	Probe Isotropy	Mod. Type	Duty Factor	PAR
835	2/7/2023	3516	EX3DV3	835	Body	54.2	0.98	Pass	Pass	Pass	GMSK	Pass	N/A
900	2/7/2023	3516	EX3DV3	900	Body	54	1.02	Pass	Pass	Pass	GMSK	Pass	N/A
1750	2/7/2023	3516	EX3DV3	1800	Body	52.9	1.41	Pass	Pass	Pass	GMSK	Pass	N/A
1900	2/7/2023	3516	EX3DV3	1900	Body	52.7	1.48	Pass	Pass	Pass	GMSK	Pass	N/A

11 APPENDIX B – Worst Case SAR Plot

DUT: SAM Nozzle; Serial: Unit 1

Communication System: UID 0, Generic 802.15.4 (0); Communication System Band: 900MHz Band (FCC); Frequency: 915 MHz;Duty Cycle: 1:1

Medium parameters used: f = 915.8 MHz; σ = 1.04 S/m; ε_r = 55.19; ρ = 1000 kg/m^3

Phantom section: Flat Section

Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY5 Configuration:

- Probe: EX3DV3 - SN3516; ConvF(10.87, 10.87, 10.87) @ 915 MHz;
- Sensor-Surface: 4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn358; Calibrated: 11/10/2022
- Phantom: ELI v5.0; Type: QDOVA002AA; Serial: TP:xxxx
- DASY52 52.10.4(1535);

Configuration/Low Channel Top/Area Scan (131x151x1): Interpolated grid: dx=1.500 mm, dy=1.500 mm

Maximum value of SAR (interpolated) = 7.37 W/kg

Configuration/Low Channel Top/Zoom Scan (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 82.01 V/m; Power Drift = -0.01 dB

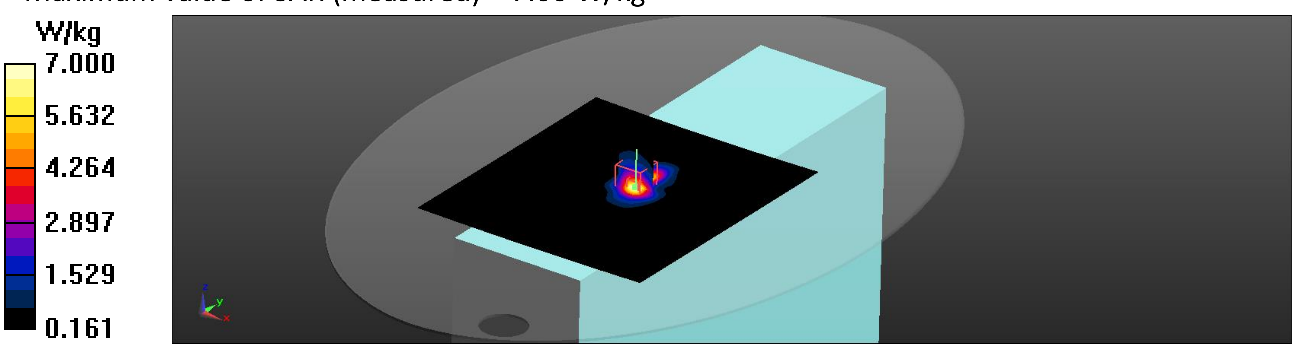
Peak SAR (extrapolated) = 12.4 W/kg

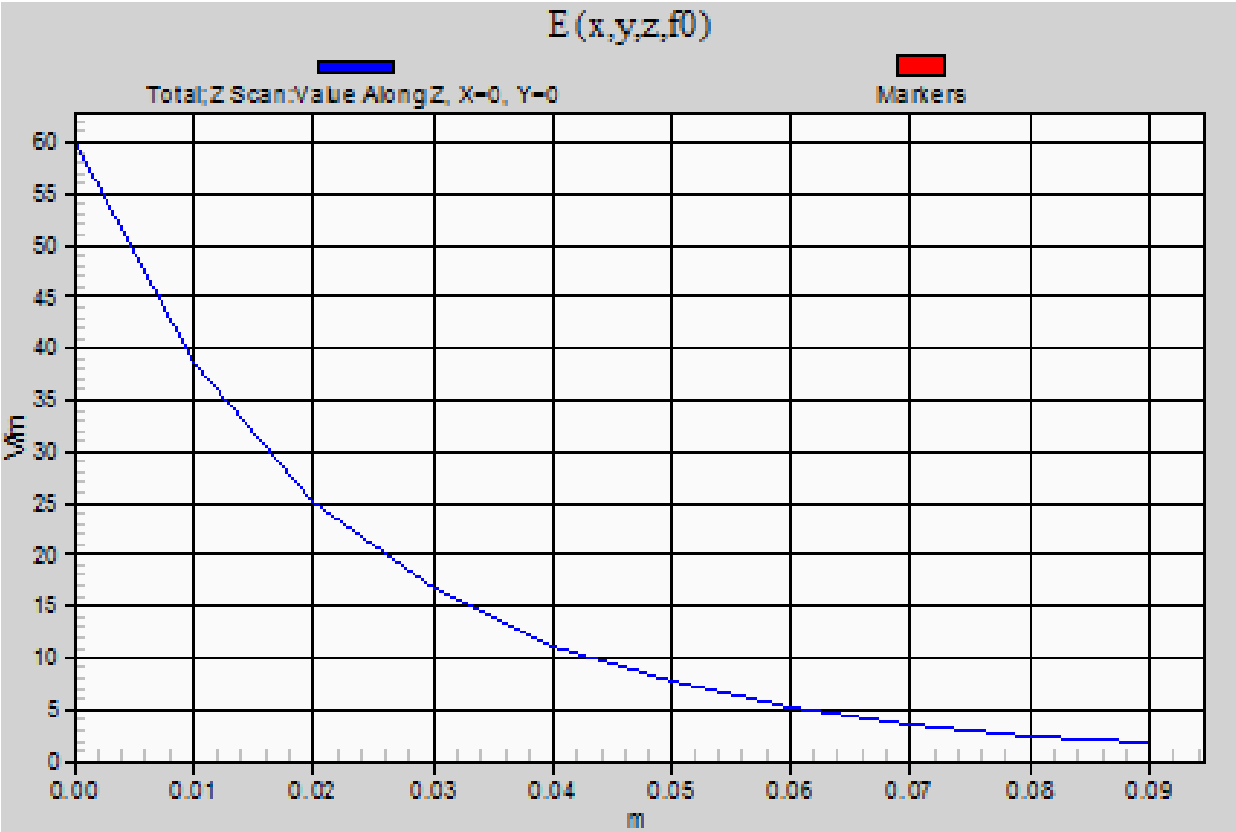
SAR(1 g) = 6.26 W/kg; SAR(10 g) = 3.44 W/kg

Smallest distance from peaks to all points 3 dB below = 9.8 mm

Ratio of SAR at M2 to SAR at M1 = 63.6%

Maximum value of SAR (measured) = 7.00 W/kg




E(x,y,z,f0)
Total;Z Scan:Value Along Z, X=0, Y=0
Markers
V/m
60
55
50
45
40
35
30
25
20
15
10
5
0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
m

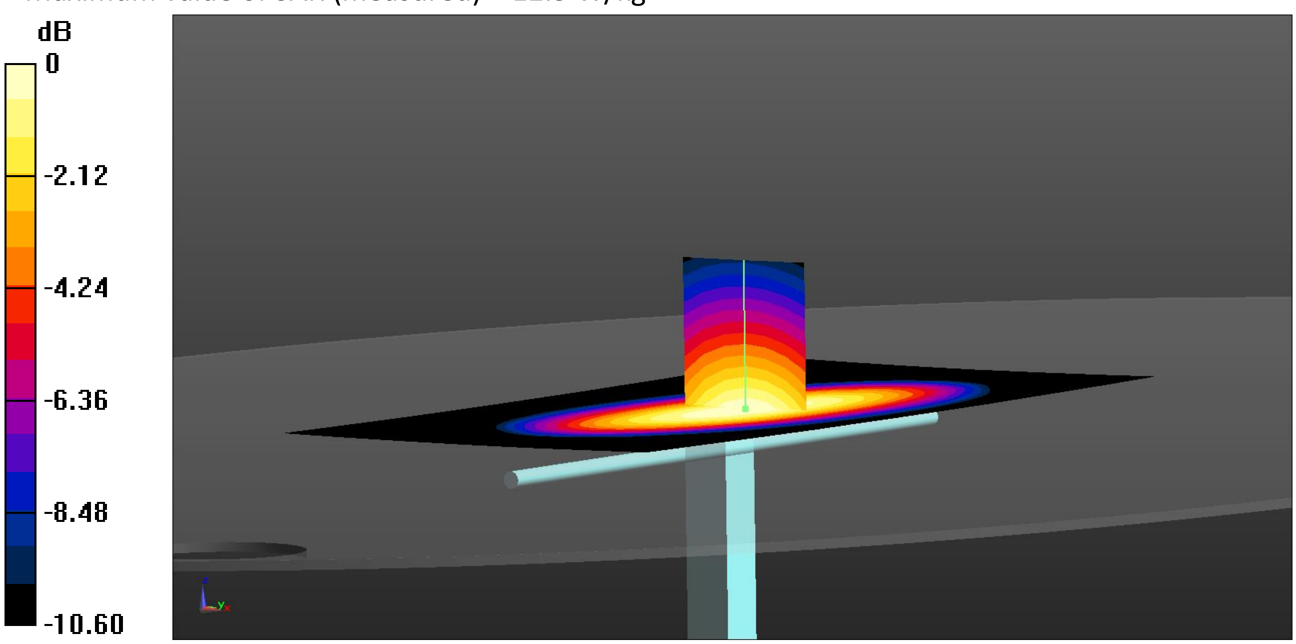
12 APPENDIX C – Dipole Validation Plots

DUT: Dipole 900 MHz D900V2; Serial: D900V2
Communication System: UID 0, Generic 802.15.4 (0); Communication System Band: 900MHz
Frequency: 900 MHz;Duty Cycle: 1:1
Medium parameters used: f = 900 MHz; σ = 1.03 S/m; ε_r = 55.48; ρ = 1000 kg/m^3
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)
DASY5 Configuration:

- Probe: EX3DV3 - SN3516; ConvF(10.87, 10.87, 10.87) @ 900 MHz;
- Sensor-Surface: 4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn358; Calibrated: 11/10/2022
- Phantom: ELI v5.0; Type: QDOVA002AA; Serial: TP:xxxx
- DASY52 52.10.4(1535);

Configuration/Dipole Validation/Area Scan (61x121x1): Interpolated grid: dx=1.500 mm, dy=1.500 mm
Maximum value of SAR (interpolated) = 12.3 W/kg

Configuration/Dipole Validation/Volume Scan (7x7x7): Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 105.5 V/m; Power Drift = 0.01 dB
Peak SAR (extrapolated) = 17.3 W/kg
SAR(1 g) = 11.5 W/kg; SAR(10 g) = 7.52 W/kg
Total Absorbed Power = 0.157 W
Maximum value of SAR (measured) = 12.5 W/kg



0 dB = 12.5 W/kg = 10.97 dBW/kg

13 APPENDIX D – SETUP PHOTOS

Figure 6 Top Side

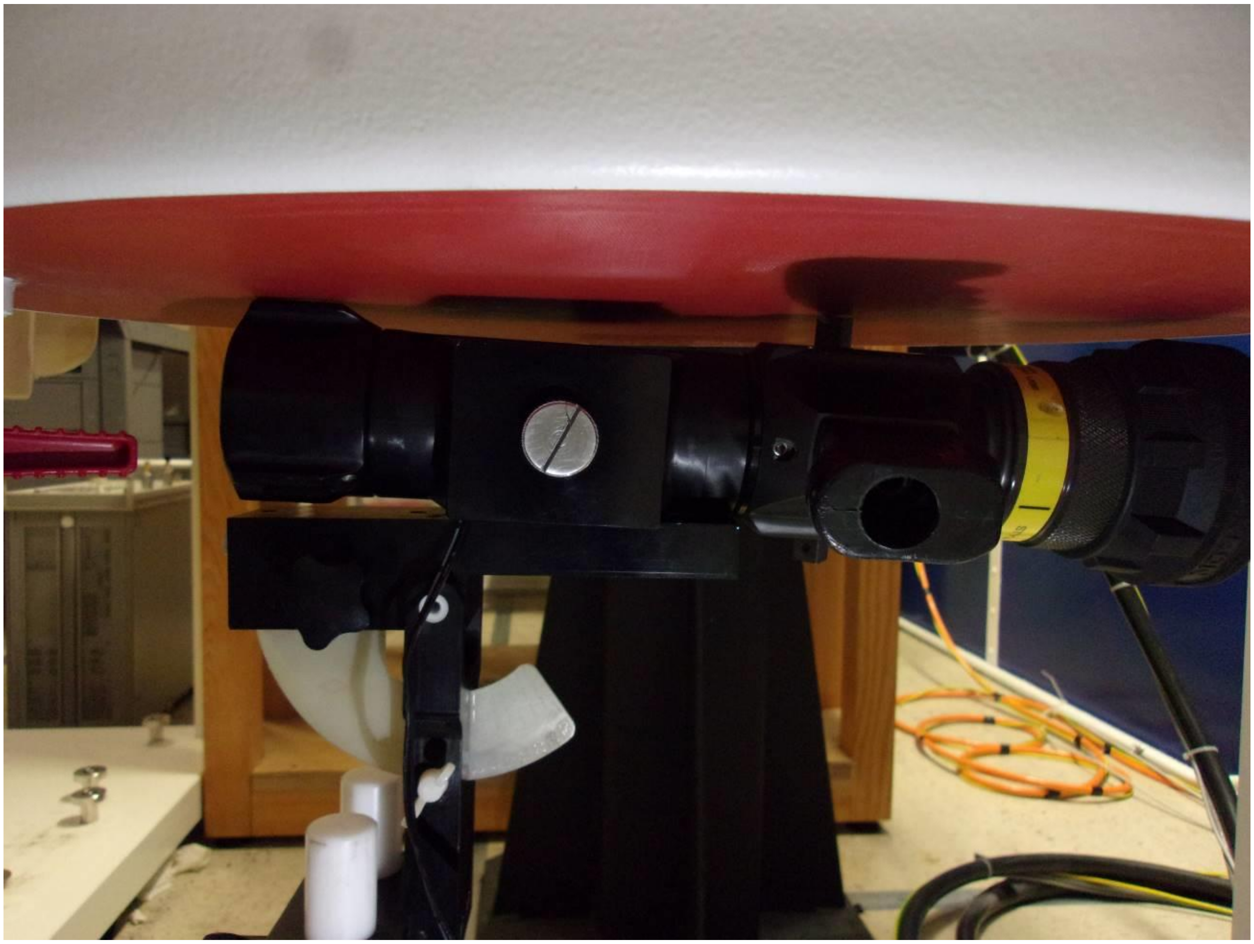


Figure 7 Right Side

Figure 8 Left Side

14 Revision History

Revision Level	Date	Report Number	Prepared By	Reviewed By	Notes
0	6/30/2022	104917132LEX-003	BL	JTS	Original Issue
1	2/9/2023	104917132LEX-003.1	BL	JTS	Updated with feedback from TCB reviewer
2	2/21/2023	104917132LEX-003.2	BL	JTS	Updated with feedback from TCB reviewer
3	2/27/2023	104917132LEX-003.3	BL	JTS	Added DCCF