ELEMENT Washington DC LLC
(formerly PCTEST)
7185 Oakland Mills Road, Columbia, MD 21046 USA
Tel. +1.410.290.6652 / Fax +1.410.290.6654
http://www.element.com

SAR EVALUATION REPORT

Applicant Name:
TSI Incorporated
500 Cardigan Road
Shoreview, Minnesota 55126 USA

Date of Testing:
01/04/2024
Test Site/Location:
Element Washington DC LLC,
Columbia, MD, USA
Lab Code: 2451B
Document Serial No.:
1M2312040121.2A22J

FCC ID: **2A22JOTMODULES**

IC: **28101-OTMODULES**

APPLICANT: **TSI INCORPORATED**

DUT Type/Apparatus/Device: Portable Sensor
Application Type: Class II Permissive Change
FCC Rule Part(s): CFR §2.1093
IC Specification(s): RSS-102 Issue 5 (March 2015), Health Canada Safety Code 6
Additional Standard(s) IEC/IEEE 62209-1528:2020
Radio Equipment Type(s): Bluetooth Device
Model(s)/HVIN: 7591-04
Additional Model(s): 7591-01, 7591-02, 7591-10, 7591-07, 7591-03, 7591-11, 7591-08,7591-06
Permissive Changes(s): See Change Document
Date of Original Certification: 07/14/2023

Equipment Class	Band & Mode	Tx Frequency	SAR	
			1g Body (W/kg)	10g Extremity (W/kg)
DSS/DTS	Bluetooth Low Energy	2402 - 2480 MHz	< 0.1	< 0.1

Only operations relevant to this permissive change were evaluated for compliance. Please see the original compliance evaluation in RF Exposure Technical Report (S/N: 1M2303240040-02-R2.2A22J). for a complete evaluation of all other operating modes. The operational description includes a description of all changed items.

This wireless portable device has been shown to be capable of compliance for localized specific absorption rate (SAR) for uncontrolled environment/general population exposure limits specified in ANSI/IEEE C95.1-1992 and has been tested in accordance with the measurement procedures specified in Section 1.9 of this report; for North American frequency bands only.

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

ACCREDITED
CERT #2041.01

The SAR Tick is an initiative of the Mobile & Wireless Forum (MWF). While a product may be considered eligible, use of the SAR Tick logo requires an agreement with the MWF. Further details can be obtained by emailing: sartick@mwfai.info.

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1 DEVICE UNDER TEST

1.1 Device Overview

Band & Mode	Operating Modes	Tx Frequency
Bluetooth Low Energy	Data	2402 - 2480 MHz

1.2 Power Reduction for SAR

There is no power reduction used for any band/mode implemented in this device for SAR purposes.

1.3 Nominal and Maximum Output Power Specifications

This device operates using the following maximum and nominal output power specifications. SAR values were scaled to the maximum allowed power to determine compliance per KDB Publication 447498 D01v06.

1.3.1 2.4 GHz Maximum Bluetooth Low Energy Output Power

Mode	Single Antenna	
	Maximum	Nominal
Bluetooth LE 1Mbps/2Mbps/125 kbps/500 kbps (in dBm)	-5.5	-7.5

1.4 DUT Antenna Locations

A diagram showing the location of the device antennas can be found in the DUT Antenna Diagram and SAR Test Setup Photographs Appendix F

Table 1-1
Device Edges/Sides for SAR Testing

Device Sides/Edges for SAR Testing						
Mode	Back	Front	Top	Bottom	Right	Left
Bluetooth Low Energy	Yes	Yes	No	Yes	Yes	No

Note: Particular DUT edges were not required to be evaluated for SAR based on the SAR exclusion threshold in KDB 447498 D01v06.

1.5 Simultaneous Transmission Capabilities

According to FCC KDB Publication 447498 D01v06, transmitters are considered to be operating simultaneously when there is overlapping transmission, with the exception of transmissions during network hand-offs with maximum hand-off duration less than 30 seconds.

This device contains multiple transmitters only when used with an accessory device described in Test Report Serial No 1M2303240040-01-R2.2A22J that may operate simultaneously, and therefore requires a simultaneous transmission analysis according to FCC KDB Publication 447498 D01v06 6.4 procedures. See section 12 for simultaneous SAR considerations.

1.6 Guidance Applied

- IEEE 1528-2013
- IEC/IEEE 62209-1528:2020
- RSS-102 Issue 5 (March 2015), Health Canada Safety Code 6
- FCC KDB Publication 865664 D01v01r04, D02v01r02 (SAR Measurements up to 6 GHz)
- FCC KDB Publication 248227 D01v02r02 (SAR Considerations for 802.11 Devices)
- FCC KDB Publication 447498 D01v06 (General SAR Guidance)
- FCC KDB Publication 941225 D07v01r02 (UMPC Mini-Tablet Devices)

1.7 Device Serial Numbers

Several samples with identical hardware were used to support SAR testing. The manufacturer has confirmed that the device(s) tested have the same physical, mechanical and thermal characteristics and are within operational tolerances expected for production units. The serial numbers used for each test are indicated alongside the results in Section 11.

1.8 Device Variants

The nine variants of the sensor are available, PM, tVOC-PID, PM + tVOC-PID, CO, TVOC, CH2O, O3, CL3 and NH3 all include the same two PCB boards. The first board, referred to as the Power PCB board, is used for charging and powering up the sensor node. The second PCB board, referred to as the Wireless board, is used for BLE communications for data transmission. The location of these boards in the sensor node is fixed and the distance to the cradle is the same on all nine configurations. This filing only evaluated the variants listed below. Please see the original filing for reference of other variants. SAR was fully evaluated on the CO variant and the worst-case measured SAR was repeated on the TVOC, CH2O, O3, CL3 and NH3 variants.

Note – The model/HVIN and variant referred to in this report are as follows.

Variant	Model/HVIN
CO	7591-06
TVOC	7591-03
CH2O	7591-07
O3	7591-08
CL2	7591-10
NH3	7591-11

2 INTRODUCTION

The FCC and Innovation, Science, and Economic Development Canada have adopted the guidelines for evaluating the environmental effects of radio frequency (RF) radiation in ET Docket 93-62 on Aug. 6, 1996 and Health Canada Safety Code 6 to protect the public and workers from the potential hazards of RF emissions due to FCC-regulated portable devices. [1]

The safety limits used for the environmental evaluation measurements are based on the criteria published by the American National Standards Institute (ANSI) for localized specific absorption rate (SAR) in IEEE/ANSI C95.1-1992 Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz [3] and Health Canada RF Exposure Guidelines Safety Code 6 [22]. The measurement procedure described in IEEE/ANSI C95.3-2002 Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields - RF and Microwave [4] is used for guidance in measuring the Specific Absorption Rate (SAR) due to the RF radiation exposure from the Equipment Under Test (EUT). These criteria for SAR evaluation are similar to those recommended by the International Committee for Non-Ionizing Radiation Protection (ICNIRP) in Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields," Report No. Vol 74. SAR is a measure of the rate of energy absorption due to exposure to an RF transmitting source. SAR values have been related to threshold levels for potential biological hazards.

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

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

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]

3 SAR MEASUREMENT SETUP

3.1 Robotic System

Measurements are performed using the DASY5, DASY6, and DASY8 automated dosimetric assessment system. The DASY5, DASY6, and DASY8 is made by Schmid & Partner Engineering AG (SPEAG) in Zurich, Switzerland and consists of a high precision robotics system (Staubli), robot controller, desktop computer, near-field probe, probe alignment sensor, and the SAM phantom containing the head or body equivalent material. The robot is a six-axis industrial robot, performing precise movements to position the probe to the location (points) of maximum electromagnetic field (EMF) (see Figure 3-1).

3.2 System Hardware

A cell controller system contains the power supply, robot controller, teach pendant (Joystick), and a remote control used to drive the robot motors. The PC consists of the SAR Measurement Software DASY52, A/D interface card, monitor, mouse, and keyboard. The Staubli Robot is connected to the cell controller to allow software manipulation of the robot. A data acquisition electronic (DAE) circuit that performs the signal amplification, signal multiplexing, A/D conversion, offset measurements, mechanical surface detection, collision detection, etc. is connected to the Electro-optical coupler (EOC). The EOC performs the conversion from the optical into digital electric signal from the DAE and transfers data to the PC card.

3.3 System Electronics

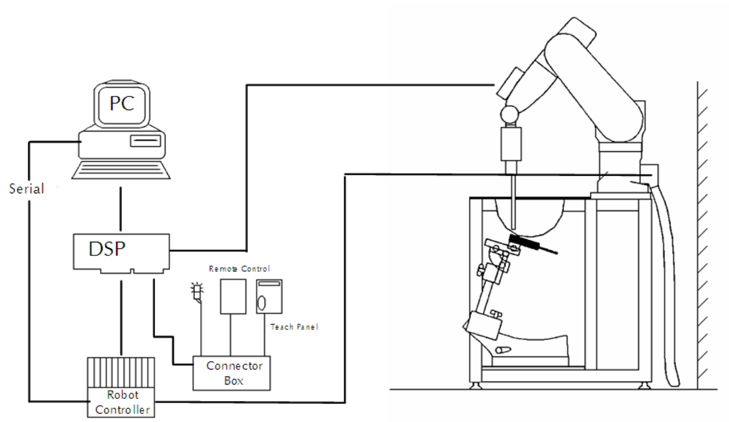


Figure 3-1
SAR Measurement System Setup

The DAE consists of a highly sensitive electrometer-grade auto-zeroing preamplifier, a channel and gain-switching multiplexer, a fast 16 bit AD-converter and a command decoder and control logic unit. Transmission to the PC-card is accomplished through an optical downlink for data and status information and an optical uplink for commands and clock lines. The mechanical probe mounting device includes two different sensor systems for frontal and sidewise probe contacts. They are also used for mechanical surface detection and probe collision detection. The robot uses its own controller with a built in VME-bus computer.

3.4 Automated Test System Specifications

Test Software:	SPEAG DASY52 Measurement Software, SPEAG DASY6 Measurement Software, and SPEAG DASY8 Measurement Software
Robot:	Stäubli Unimation Corp. Robot RX60L, Robot TX90XL
Repeatability:	0.02 mm
No. of Axes:	6

Data Acquisition Electronic System (DAE)

Data Converter

Features:	Signal Amplifier, multiplexer, A/D converter & control logic
Software:	SEMCAD X software
Connecting Lines:	Optical Downlink for data and status info Optical upload for commands and clock

PC Interface Card

Function:	Link to DAE 16-bit A/D converter for surface detection system Two Serial & Ethernet link to robotics Direct emergency stop output for robot

Phantom

Type:	SAM Twin Phantom (V4.0/5.0)/ ELI V4.0/5.0/6.0
Shell Material:	Composite
Thickness:	2.0 ± 0.2 mm

Figure 3-2
SAM Phantoms

The SAM Twin Phantom V4.0 and V5.0 is constructed of a fiberglass shell integrated in a table. The shape of the shell is based on data from an anatomical study designed to represent the 90th percentile of the population. The phantom enables the dosimetric evaluation of SAR for both left and right handed handset usage, as well as body-worn usage using the flat phantom region. Reference markings on the Phantom allow the complete setup of all predefined phantom positions and measurement grids by manually teaching three points in the robot. The shell phantom has a 2 mm shell thickness (except the ear region where shell thickness increases to 6 mm).

Figure 3-3
ELI Phantoms

ELI is constructed of a fiberglass shell and can be integrated into standard phantom tables. ELI Phantom is made for compliance testing of handheld and body-mounted wireless devices in the frequency range of 30 MHz to 6 GHz. ELI is fully compatible with the IEC/IEEE 62209-1528:2020 standard and all known tissue simulating liquids. Reference markings on the phantom allow installation of the complete setup, including all predefined phantom positions and measurement grids, by teaching three points. The shell phantom has a 2 mm shell thickness.

4 DOSIMETRIC ASSESSMENT

4.1 Measurement Procedure

The evaluation was performed using the following procedure compliant to FCC KDB Publication 865664 D01v01r04, IEC/IEEE 62209-1528:2020, and IEEE 1528-2013:

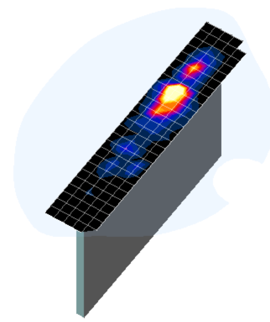


Figure 4-1
Sample SAR Area Scan

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 4-1) , IEC/IEEE 62209-1528:2020, 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 4-1) , IEC/IEEE 62209-1528:2020, and IEEE 1528-2013. On the 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 4-1. 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 4-1
Area and Zoom Scan Resolutions per FCC KDB Publication 865664 D01v01r04*

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

*Also compliant to IEEE 1528-2013 Table 6 and IEC/IEEE 62209-1528:2020 Table 4

5 DASY E-FIELD PROBE SYSTEM

5.1 Probe Measurement System

Figure 5-1
SAR System

The SAR measurements were conducted with the dosimetric probe designed in the classical triangular configuration (see Figure 5-3) and optimized for dosimetric evaluation. The probe is constructed using the thick film technique; with printed resistive lines on ceramic substrates. The probe is equipped with an optical multi-fiber line ending at the front of the probe tip. It is connected to the EOC box on the robot arm and provides an automatic detection of the phantom surface. Half of the fibers are connected to a pulsed infrared transmitter, the other half to a synchronized receiver. As the probe approaches the surface, the reflection from the surface produces a coupling from the transmitting to the receiving fibers. This reflection increases first during the approach, reaches maximum and then decreases. If the probe is flatly touching the surface, the coupling is zero. The distance of the coupling maximum to the surface is independent of the surface reflectivity and largely independent of the surface to probe angle. The DASY5 software reads the reflection during a software approach and looks for the maximum using a 2nd order curve fitting. The approach is stopped at reaching the maximum.

5.2 Probe Specifications

Model(s):	ES3DV2, ES3DV3, EX3DV4
Frequency Range:	10 MHz – 6.0 GHz (EX3DV4) 10 MHz – 4 GHz (ES3DV3, ES3DV2)
Calibration:	In head and body simulating tissue at Frequencies from 300 up to 6000MHz
Linearity:	± 0.2 dB (30 MHz to 6 GHz) for EX3DV4 ± 0.2 dB (30 MHz to 4 GHz) for ES3DV3, ES3DV2
Dynamic Range:	10 mW/kg – 100 W/kg
Probe Length:	330 mm
Probe Tip Length:	20 mm
Body Diameter:	12 mm
Tip Diameter:	2.5 mm for EX3DV4, 3.9mm for ES3DV3, ES3DV2
Tip-Center:	1 mm for EX3DV4, 2.0 mm for ES3DV3, ES3DV2

Figure 5-2
Near-Field Probe

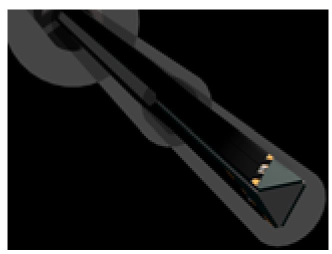


Figure 5-3
Triangular Probe Configuration

6 TEST CONFIGURATION POSITIONS

6.1 Device Holder

The device holder is made out of low-loss POM material having the following dielectric parameters: relative permittivity ε = 3 and loss tangent δ = 0.02.
phantom in a normal use configuration.

6.2 Desktop Device

The DUT shall be positioned at the distance and in the orientation to the phantom that corresponds to the intended use as specified by the manufacturer in the user instructions. All Sides of the device within 25 mm of the transmitting antenna were evaluated for SAR at 0mm distance from the phantom for 1g and 10g SAR.

6.3 UMPC Mini-Tablet Configurations

This device is intended to be used with the device associated in Test Report Serial No 1M2303240040-01-R2.2A22J and was therefore considered with for UMPC extremity SAR because of the composite device. Small hand-held tablets (and devices of similar form factors that are designed primarily for interactive hand-held use next to or near the body of users) require body SAR and extremity SAR evaluation. These types of mini-tablets are normally optimized for mobile web access and multimedia use. UMPC test procedures are applicable for devices with displays and overall diagonal dimension ≤ 20 cm. Devices are to be set up according to KDB publication 941225 D07v01r02 requirements and are configured with maximum output power during SAR assessment for a worst case SAR evaluation.

Per KDB Publication 941225 D07v01r02, UMPC mini-tablet devices must be tested for all surfaces and edges ≤ 25 mm from a transmitting antenna. A test separation distance of 0 mm was used for 1g SAR and 10g SAR to address hand and body exposure.

7 RF EXPOSURE LIMITS

7.1 Uncontrolled Environment

UNCONTROLLED ENVIRONMENTS are defined as locations where there is the exposure of individuals who have no knowledge or control of their exposure. The general population/uncontrolled exposure limits are applicable to situations in which the general public may be exposed or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential for exposure or cannot exercise control over their exposure. Members of the general public would come under this category when exposure is not employment-related; for example, in the case of a wireless transmitter that exposes persons in its vicinity.

7.2 Controlled Environment

CONTROLLED ENVIRONMENTS are defined as locations where there is exposure that may be incurred by persons who are aware of the potential for exposure, (i.e. as a result of employment or occupation). In general, occupational/controlled exposure limits are applicable to situations in which persons are exposed as a consequence of their employment, who have been made fully aware of the potential for exposure and can exercise control over their exposure. This exposure category is also applicable when the exposure is of a transient nature due to incidental passage through a location where the exposure levels may be higher than the general population/uncontrolled limits, but the exposed person is fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means.

Table 7-1
SAR Human Exposure Specified in ANSI/IEEE C95.1-1992 and Health Canada Safety Code 6

HUMAN EXPOSURE LIMITS		
	UNCONTROLLED ENVIRONMENT *General Population* (W/kg) or (mW/g)	CONTROLLED ENVIRONMENT *Occupational* (W/kg) or (mW/g)
Peak Spatial Average SAR Head	1.6	8.0
Whole Body SAR	0.08	0.4
Peak Spatial Average SAR Hands, Feet, Ankle, Wrists, etc.	4.0	20

1. The Spatial Peak value of the SAR averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.
2. The Spatial Average value of the SAR averaged over the whole body.
3. The Spatial Peak value of the SAR averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.

8 MEASUREMENT PROCEDURES

8.1 Measured and Reported SAR

Per FCC KDB Publication 447498 D01v06, when SAR is not measured at the maximum power level allowed for production units, the results must be scaled to the maximum tune-up tolerance limit according to the power applied to the individual channels tested to determine compliance. For simultaneous transmission, the measured aggregate SAR must be scaled according to the sum of the differences between the maximum tune-up tolerance and actual power used to test each transmitter. When SAR is measured at or scaled to the maximum tune-up tolerance limit, the results are referred to as *reported* SAR. The highest *reported* SAR results are identified on the grant of equipment authorization according to procedures in KDB 690783 D01v01r03.

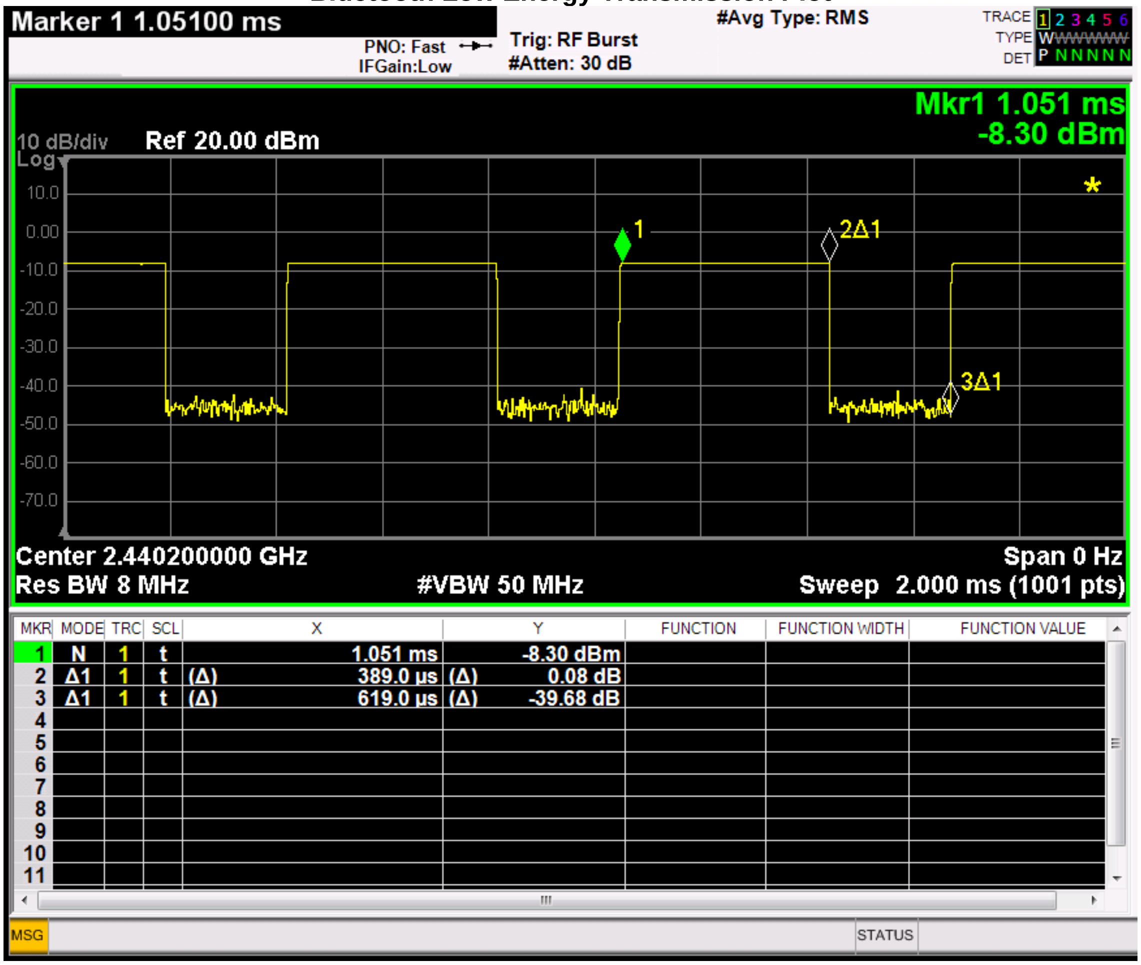
9 RF CONDUCTED POWERS

9.1 Bluetooth Low Energy Conducted Powers

Table 9-1
Bluetooth Low Energy Maximum Average RF Power

Frequency [MHz]	Data Rate [Mbps]	Channel No.	Bluetooth Mode	Peak Conducted Power	
				[dBm]	[mW]
2402	125 kbps	37	LE	-5.73	0.267
2440	125 kbps	17	LE	-6.73	0.212
2480	125 kbps	39	LE	-7.44	0.180
2402	500 kbps	37	LE	-5.76	0.265
2440	500 kbps	17	LE	-6.79	0.209
2480	500 kbps	39	LE	-7.50	0.178
2402	1 Mbps	37	LE	-5.73	0.267
2440	1 Mbps	17	LE	-6.68	0.215
2480	1 Mbps	39	LE	-7.37	0.183
2402	2 Mbps	37	LE	-5.70	0.269
2440	2 Mbps	17	LE	-6.71	0.213
2480	2 Mbps	39	LE	-7.36	0.184

Figure 9-1
Bluetooth Low Energy Transmission Plot



Equation 9-1
Bluetooth Duty Cycle Calculation

$$Duty\ Cycle = \frac{Pulse\ Width}{Period} * 100\% = \frac{0.389ms}{0.619ms} * 100\% = 62.8\%$$

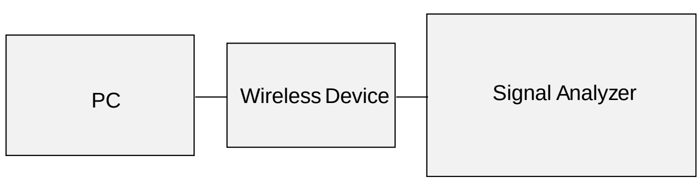


Figure 9-2
Power Measurement Setup

10 SYSTEM VERIFICATION

10.1 Tissue Verification

Table 10-1
Measured Head Tissue Properties

Calibrated for Tests Performed on:	Tissue Type	Tissue Temp During Calibration (˚C)	Measured Frequency (MHz)	Measured Conductivity, σ (S/m)	Measured Dielectric Constant, ε	TARGET Conductivity, σ (S/m)	TARGET Dielectric Constant, ε	% dev σ	% dev ε
01/04/2024	2450 Head	23.3	2300	1.711	38.952	1.670	39.500	2.46%	-1.39%
			2310	1.722	38.923	1.679	39.480	2.56%	-1.41%
			2320	1.733	38.901	1.687	39.460	2.73%	-1.42%
			2400	1.814	38.620	1.756	39.289	3.30%	-1.70%
			2450	1.872	38.464	1.800	39.200	4.00%	-1.88%
			2480	1.900	38.360	1.833	39.162	3.66%	-2.05%
			2500	1.921	38.279	1.855	39.136	3.56%	-2.19%
			2510	1.934	38.239	1.866	39.123	3.64%	-2.26%
			2535	1.966	38.139	1.893	39.092	3.86%	-2.44%
			2550	1.984	38.088	1.909	39.073	3.93%	-2.52%
			2560	1.995	38.053	1.920	39.060	3.91%	-2.58%
			2600	2.034	37.914	1.964	39.009	3.56%	-2.81%
			2650	2.092	37.694	2.018	38.945	3.67%	-3.21%
			2680	2.127	37.592	2.051	38.907	3.71%	-3.38%
			2700	2.146	37.538	2.073	38.882	3.52%	-3.46%

Note: All frequencies were measured to be within 5% of targets listed in IEC/IEEE 62209-1528:2020. Per IEC/IEEE 62209-1528:2020, since the dielectric properties of the tissue simulating are all equal or less than 5% of the target values, SAR was not scaled. The measurement uncertainty of 5% for deviation of conductivity and liquid permittivity from the target was added to the uncertainty budget in Section 13.2

The above measured tissue parameters were used in the DASY software. The DASY software was used to perform interpolation to determine the dielectric parameters at the SAR test device frequencies (per KDB Publication 865664 D01v01r04). The tissue parameters listed in the SAR test plots may slightly differ from the table above due to significant digit rounding in the software.

Per April 2019 TCB Workshop notes, single head-tissue simulating liquid specified in IEC 62209-1 is permitted to use for all SAR tests.

10.2 Test System Verification

Prior to SAR assessment, the system is verified to ±10% of the SAR measurement on the reference dipole at the time of calibration by the calibration facility. Full system validation status and result summary can be found in the SAR System Validation Appendix E.

Table 10-2
System Verification Results

System Verification TARGET & MEASURED																	
SAR System	Tissue Frequency (MHz)	Tissue Type	Date	Amb. Temp. (C)	Liquid Temp. (C)	Input Power (W)	Source SN	Probe SN	DAE	Measured SAR 1g (W/kg)	1W Target SAR 1g (W/kg)	1W Normalized SAR 1g (W/kg)	Deviation 1g (%)	Measured SAR 10g (W/kg)	1W Target SAR 10g (W/kg)	1W Normalized SAR 10g (W/kg)	Deviation 10g (%)
E	2450	HEAD	01/04/2024	20.3	23.3	0.10	981	7406	1677	5.150	53.900	51.500	-4.45%	2.320	25.400	23.200	-8.66%

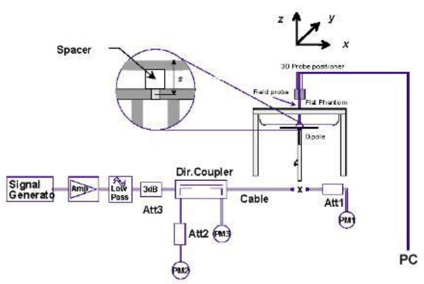


Figure 10-1
System Verification Setup Diagram

Figure 10-2
System Verification Setup Photo

11 SAR DATA SUMMARY

11.1 Standalone Body/Extremity SAR Data

Table 11-1
DSS Body/Extremity SAR

MEASUREMENT RESULTS																				
FREQUENCY		Side	Spacing	Mode	Service	Variant	Device Serial Number	Data Rate (kbps)	Maximum Allowed Power [dBm]	Conducted Power [dBm]	Power Drift [dB]	Maximum Duty Cycle (%)	Duty Cycle (%)	SAR (1g)	Scaling Factor (Cond Power)	Scaling Factor (Duty Cycle)	Reported SAR (1g)	SAR (10g)	Reported SAR (10g)	Plot #
MHz	Ch.													(W/kg)			(W/kg)	(W/kg)	(W/kg)	
2402	37	back	0 mm	Bluetooth LE	DSSS	CO	45005	125	-5.50	-5.73	0.00	100.00	62.80	0.000	1.054	1.592	0.000	0.000	0.000	
2402	37	front	0 mm	Bluetooth LE	DSSS	TVOC	45001	125	-5.50	-5.73	0.21	100.00	62.80	0.011	1.054	1.592	0.018	0.002	0.003	
2402	37	front	0 mm	Bluetooth LE	DSSS	CH2O	46004	125	-5.50	-5.73	-0.13	100.00	62.80	0.014	1.054	1.592	0.023	0.003	0.005	
2402	37	front	0 mm	Bluetooth LE	DSSS	O3	44005	125	-5.50	-5.73	-0.14	100.00	62.80	0.012	1.054	1.592	0.020	0.004	0.007	
2402	37	front	0 mm	Bluetooth LE	DSSS	CL2	46007	125	-5.50	-5.73	0.13	100.00	62.80	0.012	1.054	1.592	0.020	0.002	0.003	
2402	37	front	0 mm	Bluetooth LE	DSSS	NH3	44002	125	-5.50	-5.73	-0.12	100.00	62.80	0.015	1.054	1.592	**0.025**	0.004	**0.007**	
2402	37	front	0 mm	Bluetooth LE	DSSS	CO	45005	125	-5.50	-5.73	0.03	100.00	62.80	0.015	1.054	1.592	**0.025**	0.004	**0.007**	A1
2440	17	front	0 mm	Bluetooth LE	DSSS	CO	45005	125	-5.50	-6.73	-0.19	100.00	62.80	0.009	1.327	1.592	0.019	0.002	0.004	
2480	39	front	0 mm	Bluetooth LE	DSSS	CO	45005	125	-5.50	-7.44	0.12	100.00	62.80	0.002	1.564	1.592	0.005	0.000	0.000	
2402	37	bottom	0 mm	Bluetooth LE	DSSS	CO	45005	125	-5.50	-5.73	0.15	100.00	62.80	0.000	1.054	1.592	0.000	0.000	0.000	
2402	37	right	0 mm	Bluetooth LE	DSSS	CO	45005	125	-5.50	-5.73	0.12	100.00	62.80	0.000	1.054	1.592	0.000	0.000	0.000	
ANSI / IEEE C95.1 1992 - SAFETY LIMIT Spatial Peak Uncontrolled Exposure/General Population									Body 1.6 W/kg (mW/g), 4.0 W/kg (mW/g) averaged over 1 gram, 10 gram											

11.2 SAR Test Notes

General Notes:

1. The test data reported are the worst-case SAR values according to test procedures specified in IEEE 1528-2013, and FCC KDB Publication 447498 D01v06.
2. Per RSS-102, Issue 5 Section 3, SAR evaluations were made in accordance with the latest version of IEC/IEEE 62209-1528:2020. FCC KDB Publications listed in RSS-102 were used to supplement the limited technology specific testing protocols described in the international standards.
3. Liquid tissue depth was at least 15.0 cm for all frequencies.
4. The manufacturer has confirmed that the device(s) tested have the same physical, mechanical and thermal characteristics and are within operational tolerances expected for production units.
5. SAR results were scaled to the maximum allowed power to demonstrate compliance per FCC KDB Publication 447498 D01v06.
6. Per FCC KDB Publication 865664 D01v01r04, variability SAR tests were not required since measured SAR results for all frequency bands were less than 0.8 W/kg for 1g SAR and less than 2.0 W/kg for 10g SAR. Please see Section 13 for variability analysis.
7. Unless otherwise noted, when 10g SAR measurement is considered, a factor of 2.5 is applied to the 1g thresholds for the equivalent test cases.

Bluetooth Notes

1. Per October 2016 TCB Workshop Notes, the reported SAR was scaled to the 100% transmission duty factor to determine compliance. See Section 9 for the time domain plot and calculation for the duty factor of the device.

12 MULTI-TX AND ANTENNA SAR CONSIDERATIONS

12.1 Introduction

The following procedures adopted from FCC KDB Publication 447498 D01v06 are applicable to devices with after-market accessories. Separate equipment approval is required for accessories containing transmitter(s) that are available from the host manufacturer If the transmitter in the accessory supports standalone operations, with or without the host equipment, both conditions must be evaluated for RF exposure compliance. The connection between the two devices is mechanical and does not have an electrical component. This device (7591-04) is intended to be used with the device associated in Test Report Serial No 1M2303240040-01-R2.2A22J (TSI Smart Station). When simultaneous transmission applies, all transmitter combinations must be addressed for the accessory alone and also with the accessory operating in conjunction with the host equipment.

12.2 Simultaneous Transmission Procedures

This device (7591-04) contains transmitters that may operate simultaneously with after-market accessories (TSI Smart Station). Therefore, simultaneous transmission analysis is required. Per FCC KDB Publication, 447498 D01v06 4.3.2, IEEE 1528-2013 Section 6.3.4.1.2, and IEC/IEEE 62209-1528:2020 Section 7.4.4.2 simultaneous transmission SAR test exclusion may be applied when the sum of the 1g SAR for all the simultaneous transmitting antennas in a specific a physical test configuration is ≤1.6 W/kg for 1g SAR and ≤4.0 W/kg for 10g SAR. The different test positions in an exposure condition may be considered collectively to determine SAR test exclusion according to the sum of 1g or 10g SAR.

12.3 Body SAR Simultaneous Transmission Analysis

The standalone reported SAR in the original filing was used to determine simultaneous transmission compliance as it is more conservative. Please see the original filing for complete evaluation of simultaneous transmission analysis

12.4 Simultaneous Transmission Conclusion

The above numerical summed SAR results analysis are sufficient to determine that simultaneous transmission cases will not exceed the SAR limit and therefore no measured volumetric simultaneous SAR summation is required per FCC KDB Publication 447498 D01v06, IEEE 1528- 2013 Section 6.3.4.1, and IEC/IEEE 62209-1528:2020 Section 7.4.4.2.

13 SAR MEASUREMENT VARIABILITY

13.1 Measurement Variability

Per FCC KDB Publication 865664 D01v01r04, SAR measurement variability was assessed for each frequency band, since all measured SAR values are < 0.80 W/kg for 1g SAR and < 2.0 W/kg for 10g SAR.

13.2 Measurement Uncertainty

The measured SAR was <1.5 W/kg for 1g and <3.75 W/kg for 10g for all frequency bands. Therefore, per KDB Publication 865664 D01v01r04, the extended measurement uncertainty analysis per IEEE 1528-2013 and IEC/IEEE 62209-1528:2020 was not required.

14 EQUIPMENT LIST

Manufacturer	Model	Description	Cal Date	Cal Interval	Cal Due	Serial Number
Agilent	E4404B	Spectrum Analyzer	N/A	N/A	N/A	MY45113242
Agilent	N5182A	MXG Vector Signal Generator	11/14/2023	Annual	11/14/2024	US46240505
Agilent	8753ES	S-Parameter Vector Network Analyzer	2/8/2023	Annual	2/8/2024	US39170122
Amplifier Research	150A100C	Amplifier	CBT	N/A	CBT	350132
Anritsu	MA24106A	USB Power Sensor	4/21/2023	Annual	4/21/2024	1349503
Anritsu	MA24106A	USB Power Sensor	10/31/2023	Annual	10/31/2024	1248508
Control Company	4352	Long Stem Thermometer	9/10/2021	Triennial	9/10/2024	210774678
Control Company	4040	Therm./ Clock/ Humidity Monitor	1/17/2023	Annual	1/17/2024	160574418
Mitutoyo	500-196-30	CD-6"ASX 6Inch Digital Caliper	2/16/2022	Triennial	2/16/2025	A20238413
Keysight Technologies	N6705B	DC Power Analyzer	5/5/2021	Triennial	5/5/2024	MY53004059
Agilent	N9020A	MXA Signal Analyzer	10/17/2023	Annual	10/17/2024	MY51240479
MCL	BW-N6W5+	6dB Attenuator	CBT	N/A	CBT	1139
Mini-Circuits	BW-N20W5+	DC to 18 GHz Precision Fixed 20 dB Attenuator	CBT	N/A	CBT	N/A
Mini-Circuits	NLP-2950+	Low Pass Filter DC to 2700 MHz	CBT	N/A	CBT	N/A
Mini-Circuits	BW-N20W5	Power Attenuator	CBT	N/A	CBT	1226
Mini-Circuits	ZUDC10-83-S+	Directional Coupler	CBT	N/A	CBT	2050
Mini-Circuits	ZUDC10-83-S+	Directional Coupler	CBT	N/A	CBT	2111
Narda	4772-3	Attenuator (3dB)	CBT	N/A	CBT	9406
Narda	BW-S3W2	Attenuator (3dB)	CBT	N/A	CBT	120
Seekonk	TSF-100	Torque Wrench	6/30/2023	Annual	6/30/2024	47639-29
SPEAG	DAK-3.5	Dielectric Assessment Kit	11/13/2023	Annual	11/13/2024	1277
SPEAG	MAIA	Modulation and Audio Interference Analyzer	N/A	N/A	N/A	1379
SPEAG	D2450V2	2450 MHz SAR Dipole	11/25/2021	Triennial	11/25/2024	981
SPEAG	DAE4	Dasy Data Acquisition Electronics	7/10/2023	Annual	7/10/2024	1677
SPEAG	EX3DV4	SAR Probe	7/7/2023	Annual	7/7/2024	7406

Note: 1) All equipment was used solely within its respective calibration period. 2) 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.

15 MEASUREMENT UNCERTAINTIES

a			c	d	e= f(d,k)	f	g	h = c x f/e	i = c x g/e	k
Symbol	Uncertainty Component	IEC/IEEE 62209-1528 ref.	Tol. (± %)*	Prob. Dist.	Div.	c_i 1gm	c_i 10 gms	1gm u_i (± %)	10gms u_i (± %)	v_i
Measurement System Errors										
CF	Probe Calibration	8.4.1.1	18.6	N	2	1.0	1.0	9.3	9.3	∞
CFdrift	Probe Calibration Drift	8.4.1.2	1.7	R	1.73	1.0	1.0	1.0	1.0	∞
LIN	Probe Linearity	8.4.1.3	4.7	R	1.73	1.0	1.0	2.7	2.7	∞
BBS	Broadband Signal	8.4.1.4	2.8	R	1.73	1.0	1.0	1.6	1.6	∞
ISO	Probe Isotropy	8.4.1.5	7.6	R	1.73	1.0	1.0	4.4	4.4	∞
DAE	Other Probe and data acquisition errors	8.4.1.6	0.3	N	1	1.0	1.0	0.3	0.3	∞
AMB	RF ambient and noise	8.4.1.7	1.8	N	1	1.0	1.0	1.8	1.8	∞
Δxyz	Probe Positioning errors	8.4.1.8	±0.005 mm	N	1	0.50	0.50	0.25	0.25	∞
DAT	Data processing errors	8.4.1.9	3.5	N	1	1.0	1.0	3.5	3.5	∞
Phantom and Device Errors										
LIQ(σ)	Conductivity (Meas.)	8.4.2.1	2.5	N	1	0.78	0.71	2.0	1.8	∞
LIQ(T_σ)	Conductivity (Temp.)	8.4.2.2	2.4	R	1.73	0.78	0.71	1.1	1.0	∞
EPS	Phantom Permitivity	8.4.2.3	14.0	R	1.73	0.50	0.50	4.0	4.0	∞
DIS	Distance DUT - TSL	8.4.2.4	2.0	N	1	2.00	2.00	4.0	4.0	∞
Dxyz	Test Sample Positioning	8.4.2.5	3.1	N	1	1.0	1.0	3.1	3.1	35
H	Device Holder Uncertainty	8.4.2.6	1.7	N	1	1.0	2.0	1.7	3.4	5
MOD	Modulation Response	8.4.2.7	4.8	R	1.73	1.0	1.0	2.8	2.8	∞
TAS	Time-average SAR	8.4.2.8	1.7	R	1.73	1.0	1.0	1.0	1.0	∞
RFdrift	Output Power Variation - SAR drift measurement	8.4.2.9	2.5	N	1	1.0	1.0	2.5	2.5	∞
Corrections to the SAR result										
C(ε', σ)	Deviations to TSL targets	8.4.3.1	0.0	N	1	1.00	0.84	0.0	0.0	∞
C(ε', σ)	Deviations to TSL targets	8.4.3.1	5.0	R	1.73	0.64	0.43	1.8	1.2	∞
C(R)	SAR Scaling	8.4.3.2	0.0	R	1.73	1.0	1.0	0.0	0.0	∞
Combined Standard Uncertainty (k=1)				RSS				14.2	14.4	40
Expanded Uncertainty (95% CONFIDENCE LEVEL)				k=2				28.3	28.8	

The above measurement uncertainties are according to IEC/IEEE Std.62209-1528:2020
* Unit for Probe Positioning Errors is as indicated per IEC/IEEE Std.62209-1528:2020

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 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				12.2	12.0	191
Expanded Uncertainty (95% CONFIDENCE LEVEL)			k=2				24.4	24.0	

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

16 CONCLUSION

16.1 Measurement Conclusion

The SAR evaluation indicates that the EUT complies with the RF radiation exposure limits of the FCC and Innovation, Science, and Economic Development Canada, with respect to all parameters subject to this test. These measurements were taken to simulate the RF effects of RF exposure under worst-case conditions. Precise laboratory measures were taken to assure repeatability of the tests. The results and statements relate only to the item(s) tested.

Please note that the absorption and distribution of electromagnetic energy in the body are very complex phenomena that depend on the mass, shape, and size of the body, the orientation of the body with respect to the field vectors, and the electrical properties of both the body and the environment. Other variables that may play a substantial role in possible biological effects are those that characterize the environment (e.g. ambient temperature, air velocity, relative humidity, and body insulation) and those that characterize the individual (e.g. age, gender, activity level, debilitation, or disease). Because various factors may interact with one another to vary the specific biological outcome of an exposure to electromagnetic fields, any protection guide should consider maximal amplification of biological effects as a result of field-body interactions, environmental conditions, and physiological variables. [3]

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