FCC OET BULLETIN 65 SUPPLEMENT C 01-01
IEEE STD 1528:2003
IC RSS-102 Issue 4, March 2010
IEC 62209-2:2010

SAR EVALUATION REPORT

For
The Apple iPad, Model A1395 is a tablet device with iPod functions (music, application support, and video), 802.11a/b/g/n radio, and Bluetooth radio functions

MODEL: A1395
FCC ID: BCGA1395
IC Certification ID: 579C-A1395

REPORT NUMBER: 11U14145-1
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Prepared for
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Prepared by

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NVLAP LAB CODE 200065-0

Revision History

Rev.	Issue Date	Revisions	Revised By
--	February 13, 2012	Initial Issue	--

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1. Attestation of Test Results

Applicant:	Apple Inc.		
DUT Description	The Apple iPad, Model A1395 is a tablet device with iPod functions (music, application support, and video), 802.11a/b/g/n radio, and Bluetooth radio functions.		
Model Number	A1395, SN: DLXDV002DK29		
Test Device is	An identical prototype		
Device Category	Portable		
Exposure Category	General Population/Uncontrolled Exposure		
Date Tested	November 16 -18, 2011		
FCC / IC rule parts	Frequency Range [MHz]	Highest 1-g SAR	Limit (W/kg)
15.247 / RSS-102	2412 – 2462	0.955 W/kg (Edge 2)	1.6
15.407 / RSS-102	5150 – 5250	0.839 W/kg (Edge 2)	
	5250 – 5350	0.693 W/kg (Edge 2)	
	5500 – 5700	0.815 W/kg (Edge 2)	
15.247 / RSS-102	5725 – 5850	0.581 W/kg (Edge 2)	
Applicable Standards			Test Results
FCC OET BULLETIN 65 SUPPLEMENT C 01-01,IEEE STD 1528:2003, IC RSS-102 Issue 4, March 2010, IEC 62209-2:2010			Pass

Compliance Certification Services, Inc. (UL CCS) tested the above equipment in accordance with the requirements set forth in the above standards. All indications of Pass/Fail in this report are opinions expressed by UL CCS based on interpretations and/or observations of test results. Measurement Uncertainties were not taken into account and are published for informational purposes only. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

Note: The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. This document may not be altered or revised in any way unless done so by UL CCS and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL CCS will constitute fraud and shall nullify the document. This report must not be used by the client to claim product certification, approval, or endorsement by NVLAP, NIST, any agency of the Federal Government, or any agency of any government (NIST Handbook 150, Annex A). This report is written to support regulatory compliance of the applicable standards stated above.

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2. Test Methodology

The tests documented in this report were performed in accordance with FCC OET Bulletin 65 Supplement C Edition 01-01, IEEE STD 1528-2003, IC RSS-102 ISSUE 4, IEEE Std 1528-2003 and IEC 62209-2:2010 and the following KDB Procedures.

- 248227 SAR measurement procedures for 802.11a/b/g transmitters
- 865664 SAR 3 to 6 GHz Rev
- 447498 D01 Mobile Portable RF Exposure v04

3. Facilities and Accreditation

The test sites and measurement facilities used to collect data are located at 47173 Benicia Street, Fremont, California, USA.

UL CCS is accredited by NVLAP, Laboratory Code 200065-0. The full scope of accreditation can be viewed at http://www.ccsemc.com.

4. Calibration and Uncertainty

4.1. Measuring Instrument Calibration

The measuring equipment utilized to perform the tests documented in this report has been calibrated in accordance with the manufacturer's recommendations, and is traceable to recognized national standards.

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due date		
				MM	DD	Year
Robot - Six Axes	Stäubli	RX90BL	N/A	N/A		
Robot Remote Control	Stäubli	CS7MB	3403-91535	N/A		
DASY4 Measurement Server	SPEAG	SEUMS001BA	1041	N/A		
Probe Alignment Unit	SPEAG	LB (V2)	261	N/A		
SAM Phantom (SAM1)	SPEAG	QD000P40CA	1185	N/A		
SAM Phantom (SAM2)	SPEAG	QD000P40CA	1050	N/A		
Oval Flat Phantom (ELI 4.0)	SPEAG	QD OVA001 B	1003	N/A		
Dielectronic Probe kit	HP	85070C	N/A	N/A		
ESA Series Network Analyzer	Agilent	E5071B	MY42100131	2	2	2012
Synthesized Signal Generator	HP	83732B	US34490599	7	14	2012
E-Field Probe	SPEAG	EX3DV4	3686	1	24	2012
Thermometer, Mercury Bulb	ERTCO	639-1S	8350	7	30	2012
Data Acquisition Electronics	SPEAG	DAE3 V1	1259	5	3	2012
System Validation Dipole	SPEAG	D2450V2*	706	4	19	2012
System Validation Dipole	SPEAG	D5GHzV2	1003	8	23	2012
Power Meter	Giga-tronics	8651A	8651404	3	13	2012
Power Sensor	Giga-tronics	80701A	1834588	3	13	2012
Amplifier	Mini-Circuits	ZVE-8G	90606	N/A		
Amplifier	Mini-Circuits	ZHL-42W	D072701-5	N/A		

Notes:

*Per KDB 450824 D02 requirements for dipole calibration, UL CCS has adopted two years calibration intervals. On annual basis, each measurement dipole has been evaluated and is in compliance with the following criteria:

1. There is no physical damage on the dipole
2. System validation with specific dipole is within 10% of calibrated value.
3. Return-loss is within 20% of calibrated measurement. (See Appendix Calibration Certificate for D2450V2 SN 706 incl. extended cal. data)
4. Impedance is within 5Ω of calibrated measurement (See Appendix Calibration Certificate for D2450V2 SN 706 incl. extended cal. data)

4.2. Measurement Uncertainty

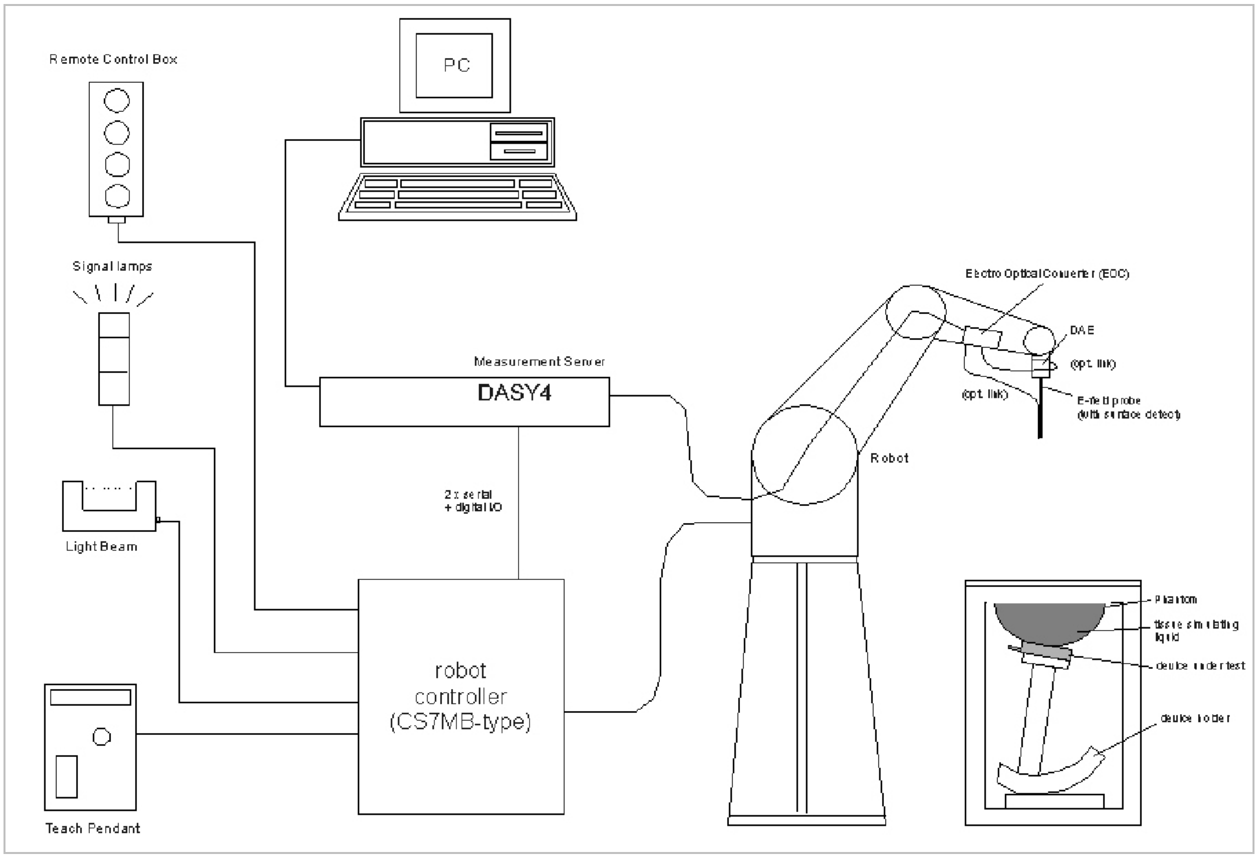
Measurement uncertainty for 300 MHz to 3 GHz averaged over 1 gram

Component	error, %	Probe Distribution	Divisor	Sensitivity	U (Xi), %
Measurement System					
Probe Calibration (k=1)	5.50	Normal	1	1	5.50
Axial Isotropy	1.15	Rectangular	1.732	0.7071	0.47
Hemispherical Isotropy	2.30	Rectangular	1.732	0.7071	0.94
Boundary Effect	0.90	Rectangular	1.732	1	0.52
Probe Linearity	3.45	Rectangular	1.732	1	1.99
System Detection Limits	1.00	Rectangular	1.732	1	0.58
Readout Electronics	0.30	Normal	1	1	0.30
Response Time	0.80	Rectangular	1.732	1	0.46
Integration Time	2.60	Rectangular	1.732	1	1.50
RF Ambient Conditions - Noise	3.00	Rectangular	1.732	1	1.73
RF Ambient Conditions - Reflections	3.00	Rectangular	1.732	1	1.73
Probe Positioner Mechanical Tolerance	0.40	Rectangular	1.732	1	0.23
Probe Positioning with respect to Phantom	2.90	Rectangular	1.732	1	1.67
Extrapolation, Interpolation and Integration	1.00	Rectangular	1.732	1	0.58
Test Sample Related					
Test Sample Positioning	2.90	Normal	1	1	2.90
Device Holder Uncertainty	3.60	Normal	1	1	3.60
Output Power Variation - SAR Drift	5.00	Rectangular	1.732	1	2.89
Phantom and Tissue Parameters					
Phantom Uncertainty (shape and thickness)	4.00	Rectangular	1.732	1	2.31
Liquid Conductivity - deviation from target	5.00	Rectangular	1.732	0.64	1.85
Liquid Conductivity - measurement	2.36	Normal	1	0.64	1.51
Liquid Permittivity - deviation from target	5.00	Rectangular	1.732	0.6	1.73
Liquid Permittivity - measurement uncertainty	4.37	Normal	1	0.6	2.62
Combined Standard Uncertainty Uc(y) =					9.91
Expanded Uncertainty U, Coverage Factor = 2, > 95 % Confidence =				19.83	%
Expanded Uncertainty U, Coverage Factor = 2, > 95 % Confidence =				1.57	dB

Measurement uncertainty for 3 to 6 GHz averaged over 1 gram

Component	error, %	Distribution	Divisor	Sensitivity	U (Xi), %
Measurement System					
Probe Calibration (k=1)	6.55	Normal	1	1	6.55
Axial Isotropy	1.15	Rectangular	1.732	0.7071	0.47
Hemispherical Isotropy	2.30	Rectangular	1.732	0.7071	0.94
Boundary Effect	0.90	Rectangular	1.732	1	0.52
Probe Linearity	3.45	Rectangular	1.732	1	1.99
System Detection Limits	1.00	Rectangular	1.732	1	0.58
Readout Electronics	1.00	Normal	1	1	1.00
Response Time	0.80	Rectangular	1.732	1	0.46
Integration Time	2.60	Rectangular	1.732	1	1.50
RF Ambient Conditions - Noise	3.00	Rectangular	1.732	1	1.73
RF Ambient Conditions - Reflections	3.00	Rectangular	1.732	1	1.73
Probe Positioner Mechanical Tolerance	0.40	Rectangular	1.732	1	0.23
Probe Positioning with respect to Phantom	2.90	Rectangular	1.732	1	1.67
Extrapolation, Interpolation and Integration	3.90	Rectangular	1.732	1	2.25
Test Sample Related					
Test Sample Positioning	1.10	Normal	1	1	1.10
Device Holder Uncertainty	3.60	Normal	1	1	3.60
Output Power Variation - SAR Drift	5.00	Rectangular	1.732	1	2.89
Phantom and Tissue Parameters					
Phantom Uncertainty (shape and thickness)	4.00	Rectangular	1.732	1	2.31
Liquid Conductivity - deviation from target	5.00	Rectangular	1.732	0.64	1.85
Liquid Conductivity - measurement	4.37	Normal	1	0.64	2.80
Liquid Permittivity - deviation from target	10.00	Rectangular	1.732	0.6	3.46
Liquid Permittivity - measurement uncertainty	4.86	Normal	1	0.6	2.92
Combined Standard Uncertainty Uc(y), %:					11.20
Expanded Uncertainty U, Coverage Factor = 1.96, > 95 % Confidence =				21.96	%
Expanded Uncertainty U, Coverage Factor = 1.96, > 95 % Confidence =				1.72	dB

5. Measurement System Description and Setup



The DASY4 system for performing compliance tests consists of the following items:

- A standard high precision 6-axis robot (Stäubli RX family) with controller, teach pendant and software. An arm extension for accommodating the data acquisition electronics (DAE).
- A dosimetric probe, i.e., an isotropic E-field probe optimized and calibrated for usage in tissue simulating liquid. The probe is equipped with an optical surface detector system.
- A data acquisition electronics (DAE) which performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. The unit is battery powered with standard or rechargeable batteries. The signal is optically transmitted to the EOC.
- The function of the measurement server is to perform the time critical tasks such as signal filtering, control of the robot operation and fast movement interrupts.
- A probe alignment unit which improves the (absolute) accuracy of the probe positioning.
- A computer operating Windows 2000 or Windows XP.
- DASY4 software.
- Remote controls with teach pendant and additional circuitry for robot safety such as warning lamps, etc.
- The SAM twin phantom enabling testing left-hand and right-hand usage.
- The device holder for handheld mobile phones.
- Tissue simulating liquid mixed according to the given recipes.
- Validation dipole kits allowing validating the proper functioning of the system.

6. Device Under Test

The Apple iPad, Model A1395 is a tablet device with iPod functions (music, application support, and video), 802.11a/b/g/n radio, and Bluetooth radio functions.	
Normal operation:	Tablet bottom face, and Tablet edges - Multiple display orientations supporting both portrait and landscape configurations
Antenna tested:	Antenna — Apple part number WiFi/BT — 631-1482 (shared with BT)
Simultaneous transmission:	WiFi 2.4 GHz cannot transmit simultaneously with Bluetooth WiFi 5 GHz bands can transmit simultaneously with Bluetooth
Assessment for SAR evaluation for Simultaneous transmission:	WiFi and BT The Bluetooth's output power is ≤ 60/f(GHz) mW, which stand-alone SAR evaluation is not required. Thus, simultaneous transmission SAR evaluation is not required for WiFi and Bluetooth antenna pair.

7. RF Output Power Verification

The following procedures had been used to prepare the DUT for the SAR test.
The client provided a special driver and program, wl_tools, which is able to control the frequency and output power of the module. Such program is not accessible by the end user.

7.1. 2.4 GHz

Mode	Channel #	Freq. (MHz)	*Target Avg Power		Measured Avg Power	
			(dBm)	(mW)	(dBm)	(mW)
802.11b	1	2412	15.7	37.15	15.7	37.15
	6	2437	15.7	37.15	15.7	37.15
	11	2462	15.6	36.31	15.7	37.15
802.11g	1	2412	14.0	25.12		
	6	2437	15.5	35.48		
	11	2462	15.0	31.62		
802.11n (HT20)	1	2412	13.0	19.95		
	6	2437	15.5	35.48		
	11	2462	14.0	25.12		

Note(s):

1. * Target power is from original SAR report 11U13601-1A1.
2. Conducted output power was not measured for 802.11g /HT20 channels because the maximum average output power from the original report was less than 1/4 dB higher than that measured on the corresponding 802.11b channels.

7.2. 5 GHz Bands

7.2.1. 5.2 GHz

Mode	Channel #	Freq. (MHz)	*Target Avg Power		Measured Avg Power	
			(dBm)	(mW)	(dBm)	(mW)
802.11a	36	5180	15.5	35.48	15.6	36.31
	40	5200	15.6	36.31	15.6	36.31
	48	5240	15.7	37.15	15.7	37.15
802.11n (HT20)	36	5180	14.0	25.12		
	40	5200	14.0	25.12		
	48	5240	14.0	25.12		

Note(s):

1. * Target power is from original SAR report 11U13601-1A1.
2. Conducted output power was not measured for 802.11g /HT20 channels because the maximum average output power from the original report was less than 1/4 dB higher than that measured on the corresponding 802.11b channels.

7.2.2. 5.3 GHz

Mode	Channel #	Freq. (MHz)	*Target Avg Power		Measured Avg Power	
			(dBm)	(mW)	(dBm)	(mW)
802.11a	52	5260	15.5	35.48	15.6	36.31
	60	5300	15.7	37.15	15.7	37.15
	64	5320	15.5	35.48	15.6	36.31
802.11n (HT20)	52	5260	15.5	35.48		
	60	5300	15.5	35.48		
	64	5320	15.5	35.48		

Note(s):

1. * Target power is from original SAR report 11U13601-1A1.
2. Conducted output power was not measured for 802.11g /HT20 channels because the maximum average output power from the original report was less than 1/4 dB higher than that measured on the corresponding 802.11b channels.

7.2.3. 5.5 GHz

Mode	Channel #	Freq. (MHz)	*Target Avg Power		Measured Avg Power	
			(dBm)	(mW)	(dBm)	(mW)
802.11a	100	5500	15.5	35.48	15.6	36.31
	120	5600	15.6	36.31	15.7	37.15
	140	5700	15.5	35.48	15.6	36.31
802.11n (HT20)	100	5500	15.5	35.48		
	120	5600	15.5	35.48		
	140	5700	15.5	35.48		

Note(s):

1. * Target power is from original SAR report 11U13601-1A1.
2. Conducted output power was not measured for 802.11g /HT20 channels because the maximum average output power from the original report was less than 1/4 dB higher than that measured on the corresponding 802.11b channels.

7.2.4. 5.8 GHz

Mode	Channel #	Freq. (MHz)	*Target Avg Power		Measured Avg Power	
			(dBm)	(mW)	(dBm)	(mW)
802.11a	149	5745	17.0	50.12	17.0	50.12
	157	5785	17.1	51.29	17.1	51.29
	165	5825	17.0	50.12	17.0	50.12
802.11n (HT20)	149	5745	17.0	50.12		
	157	5785	17.0	50.12		
	165	5825	17.0	50.12		

Note(s):

1. * Target power is from original SAR report 11U13601-1A1.
2. Conducted output power was not measured for 802.11g /HT20 channels because the maximum average output power from the original report was less than 1/4 dB higher than that measured on the corresponding 802.11b channels.

8. Tissue Dielectric Property

IEEE Std 1528-2003 Table 2

Target Frequency (MHz)	Head	
	ε_r	σ (S/m)
300	45.3	0.87
450	43.5	0.87
835	41.5	0.90
900	41.5	0.97
1450	40.5	1.20
1800 – 2000	40.0	1.40
2450	39.2	1.80
2600	39.0	1.96
3000	38.5	2.40

FCC OET Bulletin 65 Supplement C 01-01 & IC RSS-102

Target Frequency (MHz)	Head		Body	
	ε_r	σ (S/m)	ε_r	σ (S/m)
150	52.3	0.76	61.9	0.8
300	45.3	0.87	58.2	0.92
450	43.5	0.87	56.7	0.94
835	41.5	0.9	55.2	0.97
900	41.5	0.97	55	1.05
915	41.5	0.98	55	1.06
1450	40.5	1.2	54	1.3
1610	40.3	1.29	53.8	1.4
1800 – 2000	40	1.4	53.3	1.52
2450	39.2	1.8	52.7	1.95
3000	38.5	2.4	52	2.73
5000	36.2	4.45	49.3	5.07
5100	36.1	4.55	49.1	5.18
5200	36.0	4.66	49.0	5.30
5300	35.9	4.76	48.9	5.42
5400	35.8	4.86	48.7	5.53
5500	35.6	4.96	48.6	5.65
5600	35.5	5.07	48.5	5.77
5700	35.4	5.17	48.3	5.88
5800	35.3	5.27	48.2	6.00

EN 62209-1 and EN 62209-2 Table 1

Target Frequency (MHz)	Head	
	ε_r	σ (S/m)
30	55	0.75
150	52.3	0.76
300	45.3	0.87
450	43.5	0.87
835	41.5	0.9
900	41.5	0.97
915	41.5	0.98
1450	40.5	1.2
1610	40.3	1.29
1800 – 2000	40	1.4
2450	39.2	1.8
2600	39	1.96
3000	38.5	2.4
3500	37.9	2.91
4000	37.4	3.43
4500	36.8	3.94
5000	36.2	4.45
5200	36	4.66
5400	35.8	4.86
5600	35.5	5.07
5800	35.3	5.27
6000	35.1	5.48

8.1. Composition of ingredients for the tissue material used in the SAR tests

The following tissue formulations are provided for reference only as some of the parameters have not been thoroughly verified. The composition of ingredients may be modified accordingly to achieve the desired target tissue parameters required for routine SAR evaluation.

Ingredients (% by weight)	Frequency (MHz)									
	450		835		915		1900		2450	
Tissue Type	Head	Body	Head	Body	Head	Body	Head	Body	Head	Body
Water	38.56	51.16	41.45	52.4	41.05	56.0	54.9	40.4	62.7	73.2
Salt (NaCl)	3.95	1.49	1.45	1.4	1.35	0.76	0.18	0.5	0.5	0.04
Sugar	56.32	46.78	56.0	45.0	56.5	41.76	0.0	58.0	0.0	0.0
HEC	0.98	0.52	1.0	1.0	1.0	1.21	0.0	1.0	0.0	0.0
Bactericide	0.19	0.05	0.1	0.1	0.1	0.27	0.0	0.1	0.0	0.0
Triton X-100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.8	0.0
DGBE	0.0	0.0	0.0	0.0	0.0	0.0	44.92	0.0	0.0	26.7
Dielectric Constant	43.42	58.0	42.54	56.1	42.0	56.8	39.9	54.0	39.8	52.5
Conductivity (S/m)	0.85	0.83	0.91	0.95	1.0	1.07	1.42	1.45	1.88	1.78

Salt: 99+% Pure Sodium Chloride
Sugar: 98+% Pure Sucrose
Water: De-ionized, 16 MΩ+ resistivity
HEC: Hydroxyethyl Cellulose
DGBE: 99+% Di(ethylene glycol) butyl ether, [2-(2-butoxyethoxy)ethanol]
Triton X-100 (ultra pure): Polyethylene glycol mono [4-(1,1, 3, 3-tetramethylbutyl)phenyl]ether

MSL/HSL750 (Body and Head liquids for 700 – 800 MHz)

Item	Head Tissue Simulation Liquids HSL750 Muscle (body) Tissue Simulation Liquids MSL750
Type No	SL AAH 075
Manufacturer	SPEAG
The item is composed of the following ingredients:	
H^2O	Water, 35 – 58%
Sucrese	Sugar, white, refined, 40-60%
NaCl	Sodium Chloride, 0-6%
Hydroxyethel-cellulsoe	Medium Viscosity (CAS# 9004-62-0), <0.3%
Preventol-D7	Preservative: aqueous preparation, (CAS# 55965-84-9), containing 5-chloro-2-methyl-3(2H)-isothiazolone and 2-methyyl-3(2H)-isothiazolone, 0.1-0.7%

MSL/HSL1750 (Body and Head liquids for 1700 – 1800 MHz)

Item	Head Tissue Simulation Liquids HSL1750 Muscle (body) Tissue Simulation Liquids MSL1750
Type No	SL AAM 175
Manufacturer	SPEAG
-The item is composed of the following ingredients:	
H^2O	Water, 52 – 75%
C8H18O3	Diethylene glycol monobutyl ether (DGBE), 25-48%
NaCl	Sodium Chloride, <1.0%

Simulating Liquids for 5 GHz, Manufactured by SPEAG

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

8.2. Tissue dielectric parameters check results

Tissue dielectric parameters measured at the low, middle and high frequency of each operating frequency range of the test device.

Date	Freq. (MHz)	Liquid Parameters			Measured	Target	Delta (%)	Limit ±(%)
11/16/2011	Body 5500	e'	50.9406	Relative Permittivity (ϵ_r):	50.94	48.61	4.79	10
		e"	17.6785	Conductivity (σ):	5.41	5.64	-4.22	5
	Body 5600	e'	50.7696	Relative Permittivity (ϵ_r):	50.77	48.48	4.73	10
		e"	17.7944	Conductivity (σ):	5.54	5.76	-3.82	5
	Body 5700	e'	50.5987	Relative Permittivity (ϵ_r):	50.60	48.34	4.67	10
		e"	17.9029	Conductivity (σ):	5.67	5.88	-3.46	5
11/16/2011	Body 5800	e'	50.4276	Relative Permittivity (εr):	50.52	52.70	-4.13	5
		e"	18.0154	Conductivity (σ):	1.98	1.95	1.70	5
	Body 5745	e'	50.5261	Relative Permittivity (ϵ_r):	50.53	48.28	4.65	10
		e"	17.9291	Conductivity (σ):	5.73	5.93	-3.42	5
	Body 5785	e'	50.4414	Relative Permittivity (εr):	50.52	52.70	-4.13	5
		e"	17.9851	Conductivity (σ):	1.98	1.95	1.70	5
	Body 5825	e'	50.4061	Relative Permittivity (εr):	50.52	52.70	-4.13	5
		e"	18.0335	Conductivity (σ):	1.98	1.95	1.70	5
11/17/2011	Body 5200	e'	51.4023	Relative Permittivity (ϵ_r):	51.40	49.02	4.86	10
		e"	18.6475	Conductivity (σ):	5.39	5.29	1.83	5
	Body 5180	e'	51.4323	Relative Permittivity (ϵ_r):	51.43	49.05	4.86	10
		e"	18.6082	Conductivity (σ):	5.36	5.27	1.67	5
	Body 5240	e'	51.3193	Relative Permittivity (ϵ_r):	51.32	48.97	4.81	10
		e"	18.6884	Conductivity (σ):	5.45	5.34	1.94	5
	Body 5320	e'	51.1765	Relative Permittivity (ϵ_r):	51.18	48.86	4.75	10
		e"	18.8099	Conductivity (σ):	5.56	5.43	2.38	5
11/18/2011	Body 2450	e'	51.4589	Relative Permittivity (ϵ_r):	51.46	52.70	-2.36	5
		e"	13.7627	Conductivity (σ):	1.87	1.95	-3.85	5
	Body 2410	e'	51.5644	Relative Permittivity (ϵ_r):	51.56	52.76	-2.26	5
		e"	13.6130	Conductivity (σ):	1.82	1.91	-4.37	5
	Body 2435	e'	51.5011	Relative Permittivity (ϵ_r):	51.50	52.73	-2.32	5
		e"	13.7021	Conductivity (σ):	1.86	1.93	-3.93	5

9. SAR Measurement Procedures

9.1. Normal SAR measurement procedure

Step 1: Power Reference Measurement
The Power Reference Measurement and Power Drift Measurements are for monitoring the power drift of the device under test in the batch process. The Minimum distance of probe sensors to surface determines the closest measurement point to phantom surface. The minimum distance of probe sensors to surface is 2.1 mm. This distance cannot be smaller than the Distance of sensor calibration points to probe tip as defined in the probe properties.

Step 2: Area Scan
The Area Scan is used as a fast scan in two dimensions to find the area of high field values, before doing a fine measurement around the hot spot. The sophisticated interpolation routines implemented in DASY software can find the maximum locations even in relatively coarse grids. When an Area Scan has measured all reachable points, it computes the field maximal found in the scanned area, within a range of the global maximum. The range (in dB) is specified in the standards for compliance testing. For example, a 2 dB range is required in IEEE Standard 1528 and IEC 62209 standards, whereby 3 dB is a requirement when compliance is assessed in accordance with the ARIB standard (Japan). If only one Zoom Scan follows the Area Scan, then only the absolute maximum will be taken as reference. For cases where multiple maximums are detected, the number of Zoom Scans has to be increased accordingly.

Step 3: Zoom Scan
Zoom Scans are used to assess the peak spatial SAR values within a cubic averaging volume containing 1 g and 10 g of simulated tissue. The Zoom Scan measures ≥ 7x7x9 (above 4.5 GHz) or 5x5x7 (below 3 GHz) points within a cube whose base faces are centered on the maxima found in a preceding area scan job within the same procedure. When the measurement is done, the Zoom Scan evaluates the averaged SAR for 1 g and 10 g and displays these values next to the job's label.

Step 4: Power drift measurement
The Power Drift Measurement measures the field at the same location as the most recent power reference measurement within the same procedure, and with the same settings. The Power Drift Measurement gives the field difference in dB from the reading conducted within the last Power Reference Measurement. This allows a user to monitor the power drift of the device under test within a batch process. The measurement procedure is the same as Step 1.

Step 5: Z-Scan
The Z Scan measures points along a vertical straight line. The line runs along the Z-axis of a one-dimensional grid. In order to get a reasonable extrapolation, the extrapolated distance should not be larger than the step size in Z-direction.

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9.2. Volume scan procedures

Step 1: Power Reference Measurement
The Power Reference Measurement and Power Drift Measurements are for monitoring the power drift of the device under test in the batch process. The Minimum distance of probe sensors to surface determines the closest measurement point to phantom surface. The minimum distance of probe sensors to surface is 2.1 mm. This distance cannot be smaller than the Distance of sensor calibration points to probe tip as defined in the probe properties.

Step 2: Area Scan
The Area Scan is used as a fast scan in two dimensions to find the area of high field values, before doing a fine measurement around the hot spot. The sophisticated interpolation routines implemented in DASY software can find the maximum locations even in relatively coarse grids. When an Area Scan has measured all reachable points, it computes the field maximal found in the scanned area, within a range of the global maximum. The range (in dB) is specified in the standards for compliance testing. For example, a 2 dB range is required in IEEE Standard 1528 and IEC 62209 standards, whereby 3 dB is a requirement when compliance is assessed in accordance with the ARIB standard (Japan). If only one Zoom Scan follows the Area Scan, then only the absolute maximum will be taken as reference. For cases where multiple maximums are detected, the number of Zoom Scans has to be increased accordingly.

Step 3: Zoom Scan
Zoom Scans are used to assess the peak spatial SAR values within a cubic averaging volume containing 1 g and 10 g of simulated tissue. The Zoom Scan measures ≥ 7x7x9 (above 4.5 GHz) or 5x5x7 (below 3 GHz) points within a cube whose base faces are centered on the maxima found in a preceding area scan job within the same procedure. When the measurement is done, the Zoom Scan evaluates the averaged SAR for 1 g and 10 g and displays these values next to the job's label.

Step 4: Volume Scan
Volume Scans are used to assess peak SAR and averaged SAR measurements in largely extended 3-dimensional volumes within any phantom. This measurement does not need any previous area scan. The grid can be anchored to a user specific point or to the current probe location.

Step 5: Power drift measurement
The Power Drift Measurement measures the field at the same location as the most recent power reference measurement within the same procedure, and with the same settings. The Power Drift Measurement gives the field difference in dB from the reading conducted within the last Power Reference Measurement. This allows a user to monitor the power drift of the device under test within a batch process. The measurement procedure is the same as Step 1.

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10. System Performance Check

The system performance check is performed prior to any usage of the system in order to verify SAR system measurement accuracy. The system performance check verifies that the system operates within its specifications of ±10%.

10.1. System performance check measurement conditions

- The measurements were performed in the flat section of the TWIN SAM or ELI phantom, shell thickness: 2.0 ±0.2 mm (bottom plate) filled with Body or Head simulating liquid of the following parameters.
- The DASY system with an E-Field Probe was used for the measurements.
- The dipole was mounted on the small tripod so that the dipole feed point was positioned below the center marking of the flat phantom section and the dipole was oriented parallel to the body axis (the long side of the phantom). The standard measuring distance was 10 mm (above 1 GHz) and 15 mm (below 1 GHz) from dipole center to the simulating liquid surface.
- The coarse grid with a grid spacing of 15 mm was aligned with the dipole.
  For 5 GHz band - The coarse grid with a grid spacing of 10 mm was aligned with the dipole.
- Special 7x7x7 fine cube was chosen for cube.
- Distance between probe sensors and phantom surface was set to 3 mm.
  For 5 GHz band - Distance between probe sensors and phantom surface was set to 2.5 mm
- The dipole input power (forward power) was 100 mW.
- The results are normalized to 1 W input power.

10.2. Reference SAR values for system performance check

The reference SAR values can be obtained from the calibration certificate of system validation dipoles

System Dipole	Serial No.	Cal. Date	Freq. (MHz)	SAR Measured (mW/g)		
				1g/10g	Head	Body
D2450V2	706	4/19/11	2450	1g	51.6	52.4
				10g	24.4	24.5
				10g	24.6	22.7
D5GHzV2	1003	8/23/11	5200	1g	76.5	74.5
				10g	21.8	20.8
			5500	1g	80.9	80.0
				10g	23.1	22.3
			5800	1g	76.3	76.3
				10g	21.7	21.2

10.3. System Performance Check Results

Date Tested	System dipole		Measured (Normalized to 1 W)		Target	Delta (%)	Tolerance (%)
11/16/11	Body	5500	SAR_{1g}:	75.9	80	-5.12	±10
			SAR_{10g}:	21.4	22.3	-4.04	
11/16/11	Body	5800	SAR_{1g}:	70.8	76.3	-7.21	±10
			SAR_{10g}:	20.0	21.2	-5.66	
11/17/11	Body	5200	SAR_{1g}:	77.0	74.5	3.36	±10
			SAR_{10g}:	21.8	20.8	4.81	
11/18/11	Body	2450	SAR_{1g}:	51.0	52.4	-2.67	±10
			SAR_{10g}:	23.7	24.5	-3.27	

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11. Summary of Test Configurations

Test Configuration	Antenna-to-Edge/Surface distance	SAR Require	Comments
Rear	8.0 mm	Yes	SAR evaluation was performed with the DUT bottom in direct contact with oval phantom flat section (0 mm separation).
Edge 1	44.6 mm	Yes	SAR evaluation was performed with the DUT side in direct contact with oval phantom flat section (0 mm separation).
Edge 2	3.75 mm	Yes	SAR evaluation was performed with the DUT top in direct contact with oval phantom flat section (0 mm separation).
Edge 3	112 mm	No	
Edge 4	227 mm	No	

12. SAR Test Results

12.1. 2.4 GHz

Test mode reduction considerations

SAR is not required for 802.11g /HT20 channels when the maximum average output power is less than 1/4 dB higher than that measured on the corresponding 802.11b channels as per KDB 248227.

Test position	Mode	Ch No.	Freq. (MHz)	Avg Pwr (dBm)	SAR (mW/g)		Note
					1-g	10-g	
Rear	802.11b	1	2412	15.7			1
		6	2437	15.7	0.002	0.0002	
		11	2462	15.7			1
Edge 2	802.11b	1	2412	15.7	0.893	0.306	
		6	2437	15.7	**0.955**	**0.330**	
		11	2462	15.7	0.762	0.264	
Edge 1	802.11b	1	2412	15.7			1
		6	2437	15.7	0.043	0.020	
		11	2462	15.7			1

Note(s):

1. Testing was performed on the channel with the highest output power only as the SAR was ≤ 0.8 W/kg with the operating frequency band having a range of < 100 MHz. Per KDB 447498 1) e) i)

12.2. 5GHz Bands

Test mode reduction considerations

SAR is not required for 802.11n /HT20 channels when the maximum average output power is less than 1/4 dB higher than that measured on the corresponding 802.11b channels as per KDB 248227.

12.2.1. 5.2 GHz

Test position	Mode	Ch No.	Freq. (MHz)	Avg Pwr (dBm)	SAR (mW/g)		Note
					1-g	10-g	
Rear	802.11a	36	5180	15.6			1
		40	5200	15.6	0.047	0.016	
		48	5240	15.7			1
Edge 2	802.11a	36	5180	15.6	0.835	0.315	
		40	5200	15.6	**0.839**	**0.294**	
		48	5240	15.7	0.744	0.252	
Edge 1	802.11a	36	5180	15.6			1
		40	5200	15.6	0.015	0.006	
		48	5240	15.7			1

Note(s):

1. Testing was performed on the channel with the highest output power only as the SAR was ≤ 0.8 W/kg with the operating frequency band having a range of < 100 MHz. Per KDB 447498 1) e) i)

12.2.2. 5.3 GHz

Test position	Mode	Ch No.	Freq. (MHz)	Avg Pwr (dBm)	SAR (mW/g)		Note
					1-g	10-g	
Rear	802.11a	52	5260	15.6			1
		60	5300	15.7	0.065	0.024	
		64	5320	15.6			1
Edge 2	802.11a	52	5260	15.6			1
		60	5300	15.7	**0.693**	**0.237**	
		64	5320	15.6			1
Edge 1	802.11a	52	5260	15.6			1
		60	5300	15.7	0.018	0.005	
		64	5320	15.6			1

Note(s):

1. Testing was performed on the channel with the highest output power only as the SAR was ≤ 0.8 W/kg with the operating frequency band having a range of < 100 MHz. Per KDB 447498 1) e) i)

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12.2.3. 5.5 GHz

Test position	Mode	Ch No.	Freq. (MHz)	Avg Pwr (dBm)	SAR (mW/g)		Note
					1-g	10-g	
Rear	802.11a	100	5500	15.6			1
		120	5600	15.7	0.050	0.018	
		140	5700	15.6			1
Edge 2	802.11a	100	5500	15.6	0.781	0.271	
		120	5600	15.7	**0.815**	**0.273**	
		140	5700	15.6	0.750	0.247	
Edge 1	802.11a	100	5500	15.6			1
		120	5600	15.7	0.040	0.012	
		140	5700	15.6			1

Note(s):

1. Testing was performed on the channel with the highest output power only as the SAR was ≤ 0.4 W/kg with the operating frequency band having a range of ≤ 200 MHz. Per KDB 447498 1) e) ii).

12.2.4. 5.8 GHz

Test position	Mode	Ch No.	Freq. (MHz)	Avg Pwr (dBm)	SAR (mW/g)		Note
					1-g	10-g	
Rear	802.11a	149	5745	17.0			
		157	5785	17.1	0.073	0.025	
		165	5825	17.0			
Edge 2	802.11a	149	5745	17.0			
		157	5785	17.1	**0.581**	**0.217**	
		165	5825	17.0			
Edge 1	802.11a	149	5745	17.0			
		157	5785	17.1	0.074	0.023	
		165	5825	17.0			

Note(s):

1. Testing was performed on the channel with the highest output power only as the SAR was ≤ 0.8 W/kg with the operating frequency band having a range of < 100 MHz. Per KDB 447498 1) e) i)

13. Summary of Highest SAR Values for each Frequency Band and Mode

Technology/Band	Test configuration		Mode	Separation distance (mm)	Highest 1g SAR (W/kg)
WiFi 2.4 GHz	Body:	Edge 2	802.11b	0	0.955
WiFi 5.2 GHz	Body:	Edge 2	802.11a	0	0.839
WiFi 5.3 GHz	Body:	Edge 2	802.11a	0	0.693
WiFi 5.5 GHz	Body:	Edge 2	802.11a	0	0.815
WiFi 5.8 GHz	Body:	Edge 2	802.11a	0	0.581

14. Worst-case SAR Plots

Date/Time: 11/18/2011 9:36:27 AM

Test Laboratory: UL CCS SAR Lab D

2.4GHz Body

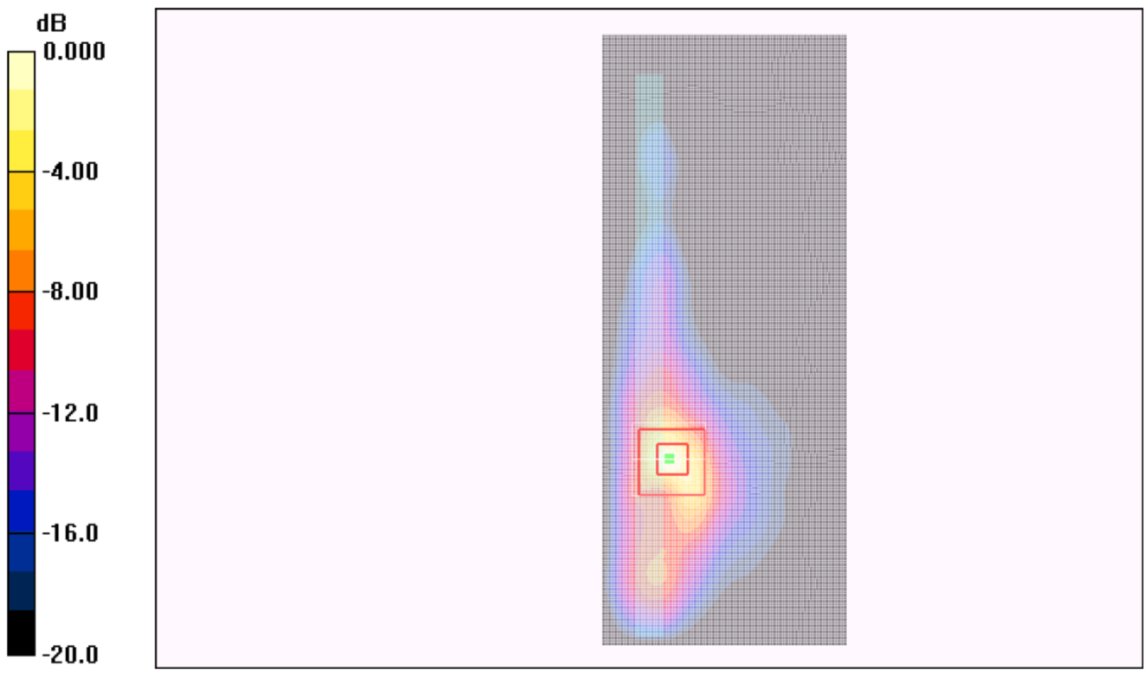
Communication System: 802.11b/g 2.4GHz; Frequency: 2437 MHz; Duty Cycle: 1:1
Medium parameters used (interpolated): f = 2437 MHz; σ = 1.98 mho/m; ε_r = 52.1; ρ = 1000 kg/m^3
Phantom section: Flat Section

Room Ambient Temperature: 24.0 deg. C; Liquid Temperature: 23.0 deg. C

DASY4 Configuration:
- Area Scan setting - Find Secondary Maximum Within: 2.0 dB and with a peak SAR value greater than 0.0012W/kg
- Probe: EX3DV4 - SN3686; ConvF(6.86, 6.86, 6.86); Calibrated: 1/24/2011
- Sensor-Surface: 2.5mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1259; Calibrated: 5/3/2011
- Phantom: Flat Phantom ELI4.0; Type: QDOVA001BB; Serial: SN:1017
- Measurement SW: DASY4, V4.7 Build 80; Post processing SW: SEMCAD, V1.8 Build 186

Edge 2_ Ch6/Area Scan (81x201x1): Measurement grid: dx=10mm, dy=10mm
Info: Interpolated medium parameters used for SAR evaluation.
Maximum value of SAR (interpolated) = 1.59 mW/g

Edge 2_ Ch6/Zoom Scan (7x7x9)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=2.5mm
Reference Value = 27.8 V/m; Power Drift = -0.111 dB
Peak SAR (extrapolated) = 2.92 W/kg
SAR(1 g) = 0.955 mW/g; SAR(10 g) = 0.330 mW/g
Info: Interpolated medium parameters used for SAR evaluation.
Maximum value of SAR (measured) = 1.64 mW/g



0 dB = 1.64mW/g

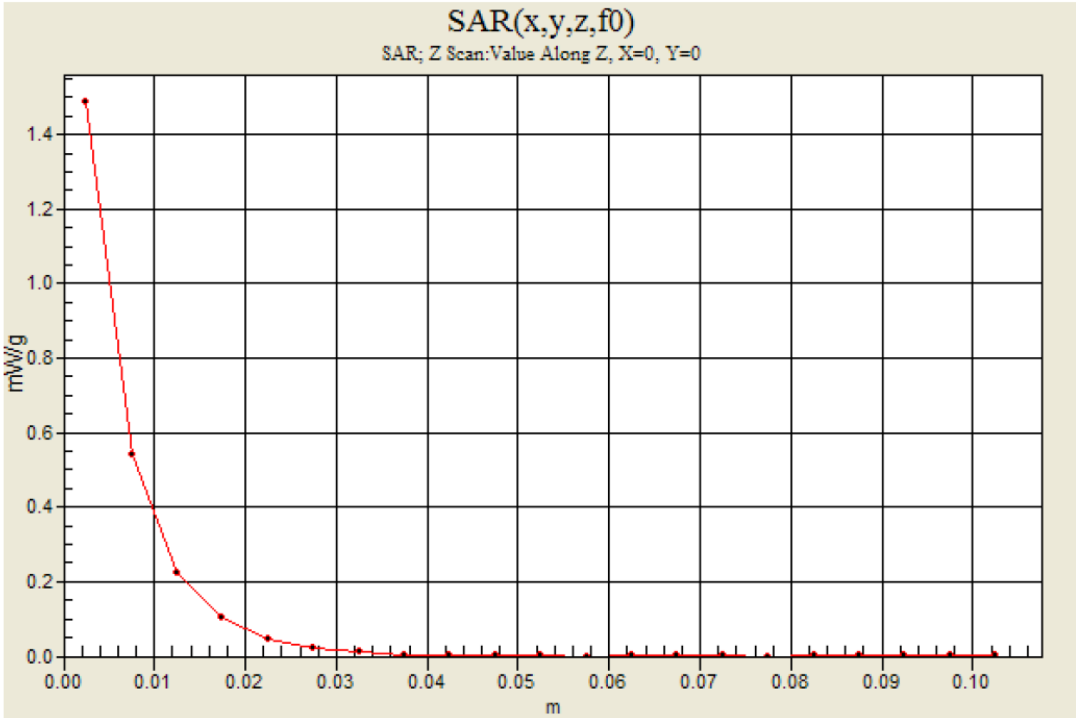
Date/Time: 11/18/2011 10:05:44 AM

Test Laboratory: UL CCS SAR Lab D

2.4GHz Body

Communication System: 802.11b/g 2.4GHz; Frequency: 2437 MHz; Duty Cycle: 1:1

Edge 2_ Ch6/Z Scan (1x1x21): Measurement grid: dx=20mm, dy=20mm, dz=5mm
Info: Interpolated medium parameters used for SAR evaluation.
Maximum value of SAR (measured) = 1.49 mW/g



Date/Time: 11/17/2011 1:45:39 PM

Test Laboratory: UL CCS SAR Lab D

5GHz_Body

DUT: Apple; Type: 17 inch; Serial: N/A

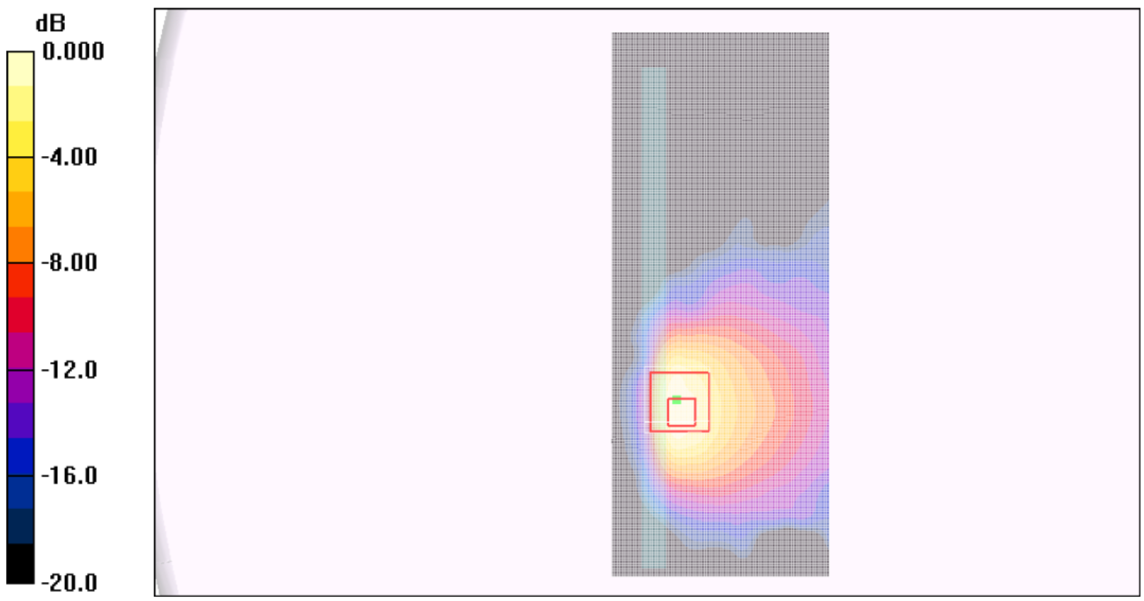
Communication System: 802.11abgn; Frequency: 5200 MHz; Duty Cycle: 1:1
Medium parameters used: f = 5200 MHz; σ = 5.39 mho/m; ε_r = 51.4; ρ = 1000 kg/m^3
Phantom section: Flat Section

Room Ambient Temperature: 25.0 deg. C; Liquid Temperature: 24.0 deg. C

DASY4 Configuration:
- Area Scan setting - Find Secondary Maximum Within: 2.0 dB and with a peak SAR value greater than 0.0012W/kg
- Probe: EX3DV4 - SN3686; ConvF(3.98, 3.98, 3.98); Calibrated: 1/24/2011
- Sensor-Surface: 2.5mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1259; Calibrated: 5/3/2011
- Phantom: Flat Phantom ELI4.0; Type: QDOVA001BB; Serial: SN:1017
- Measurement SW: DASY4, V4.7 Build 80; Post processing SW: SEMCAD, V1.8 Build 186

Edge 2_ Ch40/Area Scan (81x201x1): Measurement grid: dx=10mm, dy=10mm
Maximum value of SAR (interpolated) = 1.43 mW/g

Edge 2_ Ch40/Zoom Scan (7x7x9)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=2.5mm
Reference Value = 15.4 V/m; Power Drift = 0.072 dB
Peak SAR (extrapolated) = 2.61 W/kg
SAR(1 g) = 0.839 mW/g; SAR(10 g) = 0.294 mW/g
Maximum value of SAR (measured) = 1.38 mW/g



0 dB = 1.38mW/g

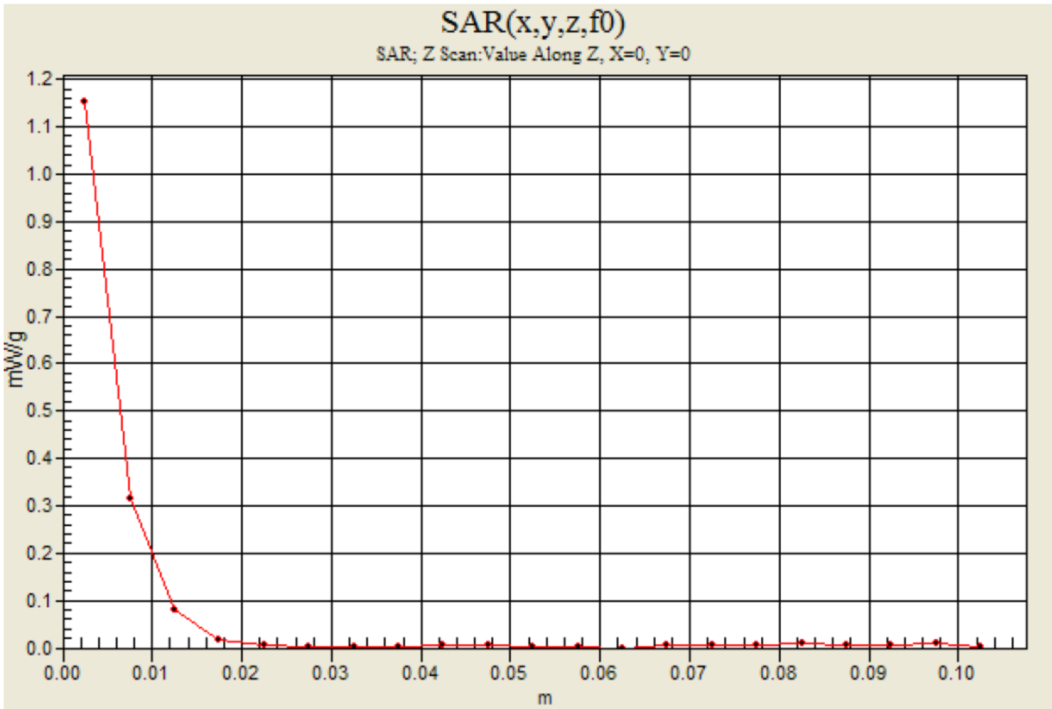
Date/Time: 11/17/2011 2:15:08 PM

Test Laboratory: UL CCS SAR Lab D

5GHz_Body

Communication System: 802.11abgn; Frequency: 5200 MHz; Duty Cycle: 1:1

Edge 2_ Ch40/Z Scan (1x1x21): Measurement grid: dx=20mm, dy=20mm, dz=5mm
Maximum value of SAR (measured) = 1.15 mW/g



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Test Laboratory: UL CCS SAR Lab D

5GHz Body

DUT: Apple; Type: 17 inch; Serial: N/A

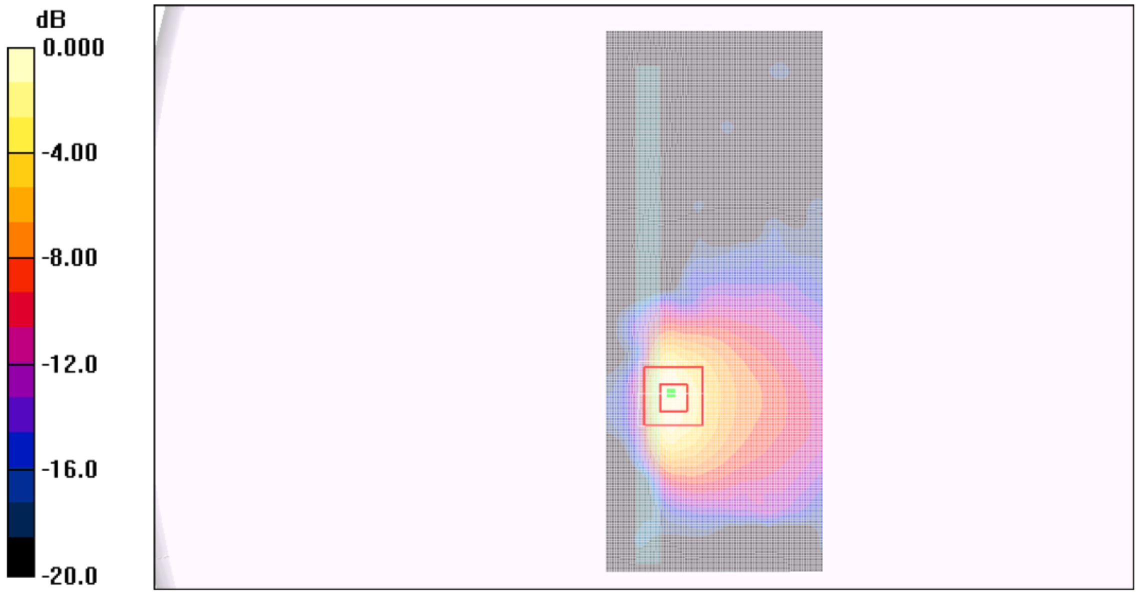
Communication System: 802.11abgn; Frequency: 5300 MHz; Duty Cycle: 1:1
Medium parameters used: f = 5300 MHz; σ = 5.54 mho/m; ε_r = 51.2; ρ = 1000 kg/m^3
Phantom section: Flat Section

Room Ambient Temperature: 25.0 deg. C; Liquid Temperature: 24.0 deg. C

DASY4 Configuration:
- Area Scan setting - Find Secondary Maximum Within: 2.0 dB and with a peak SAR value greater than 0.0012W/kg
- Probe: EX3DV4 - SN3686; ConvF(3.7, 3.7, 3.7); Calibrated: 1/24/2011
- Sensor-Surface: 2.5mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1259; Calibrated: 5/3/2011
- Phantom: Flat Phantom ELI4.0; Type: QDOVA001BB; Serial: SN:1017
- Measurement SW: DASY4, V4.7 Build 80; Post processing SW: SEMCAD, V1.8 Build 186

Edge 2_ Ch60/Area Scan (81x201x1): Measurement grid: dx=10mm, dy=10mm
Maximum value of SAR (interpolated) = 1.30 mW/g

Edge 2_ Ch60/Zoom Scan (7x7x9)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=2.5mm
Reference Value = 13.3 V/m; Power Drift = 0.147 dB
Peak SAR (extrapolated) = 2.28 W/kg
SAR(1 g) = 0.693 mW/g; SAR(10 g) = 0.237 mW/g
Maximum value of SAR (measured) = 1.19 mW/g



0 dB = 1.19mW/g

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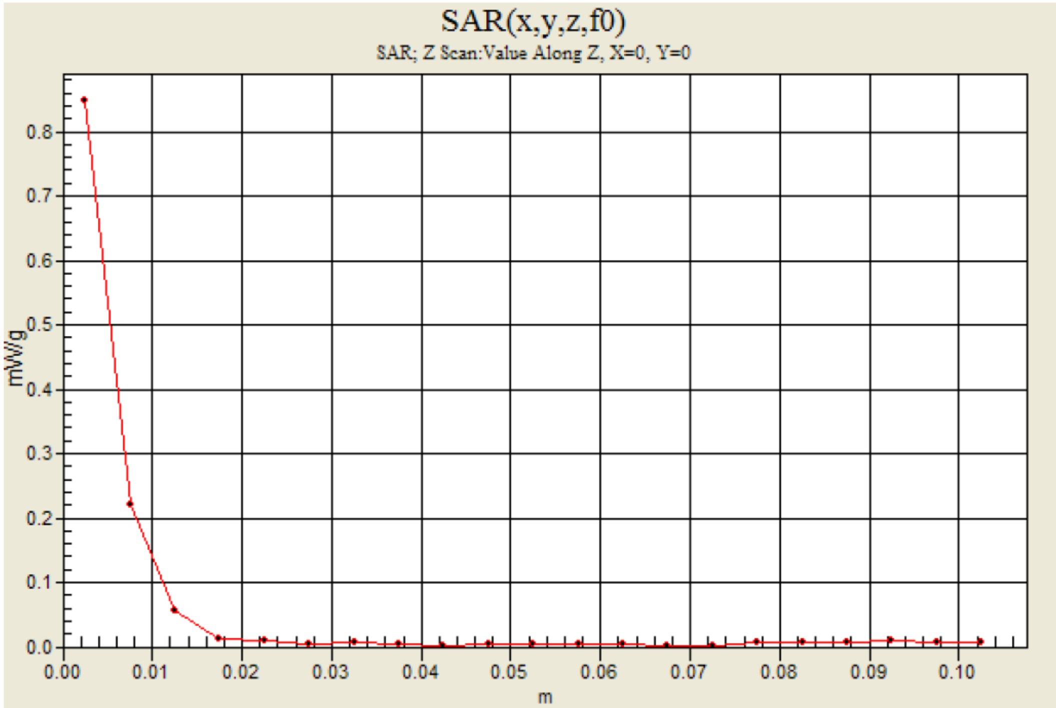
Test Laboratory: UL CCS SAR Lab D

5GHz Body

Communication System: 802.11abgn; Frequency: 5300 MHz; Duty Cycle: 1:1

Edge 2_ Ch60/Z Scan (1x1x21): Measurement grid: dx=20mm, dy=20mm, dz=5mm
Maximum value of SAR (measured) = 0.848 mW/g



Date/Time: 11/16/2011 4:56:42 PM

Test Laboratory: UL CCS SAR Lab D

5GHz_Body

DUT: Apple; Type: 17 inch; Serial: N/A

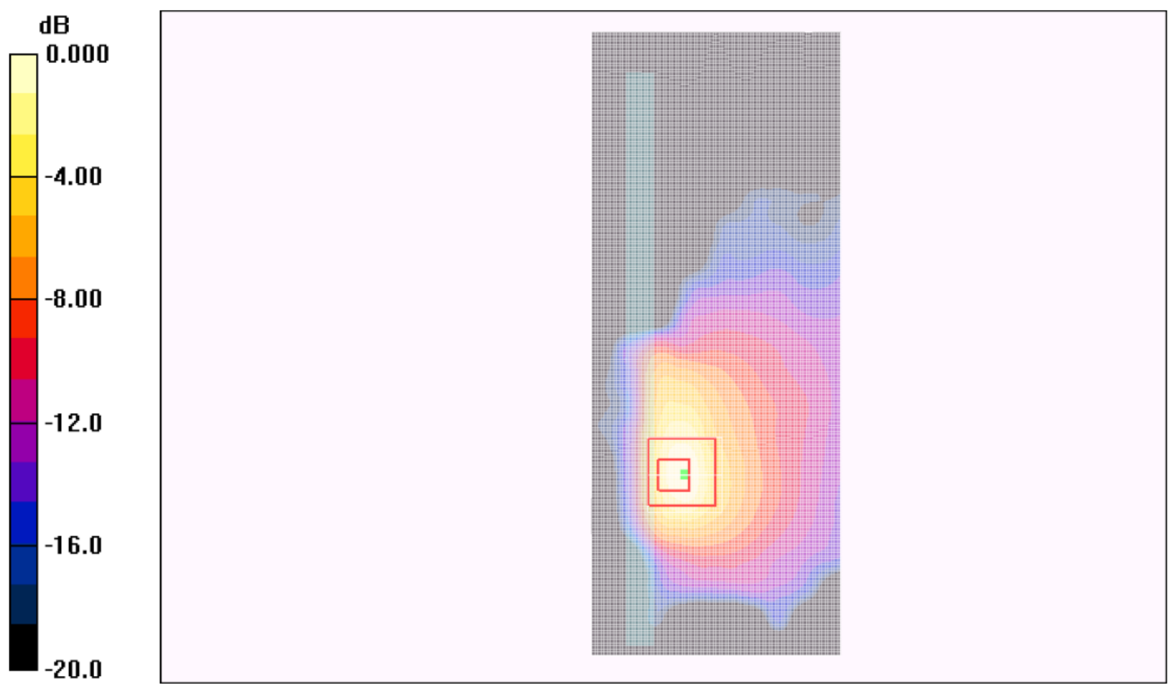
Communication System: 802.11abgn; Frequency: 5600 MHz; Duty Cycle: 1:1
Medium parameters used: f = 5600 MHz; σ = 5.54 mho/m; ε_r = 50.8; ρ = 1000 kg/m^3
Phantom section: Flat Section

Room Ambient Temperature: 25.0 deg. C; Liquid Temperature: 24.0 deg. C

DASY4 Configuration:
- Area Scan setting - Find Secondary Maximum Within: 2.0 dB and with a peak SAR value greater than 0.0012W/kg
- Probe: EX3DV4 - SN3686; ConvF(3.29, 3.29, 3.29); Calibrated: 1/24/2011
- Sensor-Surface: 2.5mm (Mechanical Surface Detection (Locations From Previous Scan Used))Sensor-Surface: 2.5mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1259; Calibrated: 5/3/2011
- Phantom: Flat Phantom ELI4.0; Type: QDOVA001BB; Serial: SN:1017
- Measurement SW: DASY4, V4.7 Build 80; Post processing SW: SEMCAD, V1.8 Build 186

Edge 2_ Ch120/Area Scan (81x201x1): Measurement grid: dx=10mm, dy=10mm
Maximum value of SAR (interpolated) = 1.41 mW/g

Edge 2_ Ch120/Zoom Scan (7x7x9)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=2.5mm
Reference Value = 15.1 V/m; Power Drift = 0.166 dB
Peak SAR (extrapolated) = 2.75 W/kg
SAR(1 g) = 0.815 mW/g; SAR(10 g) = 0.273 mW/g
Maximum value of SAR (measured) = 1.46 mW/g



0 dB = 1.46mW/g

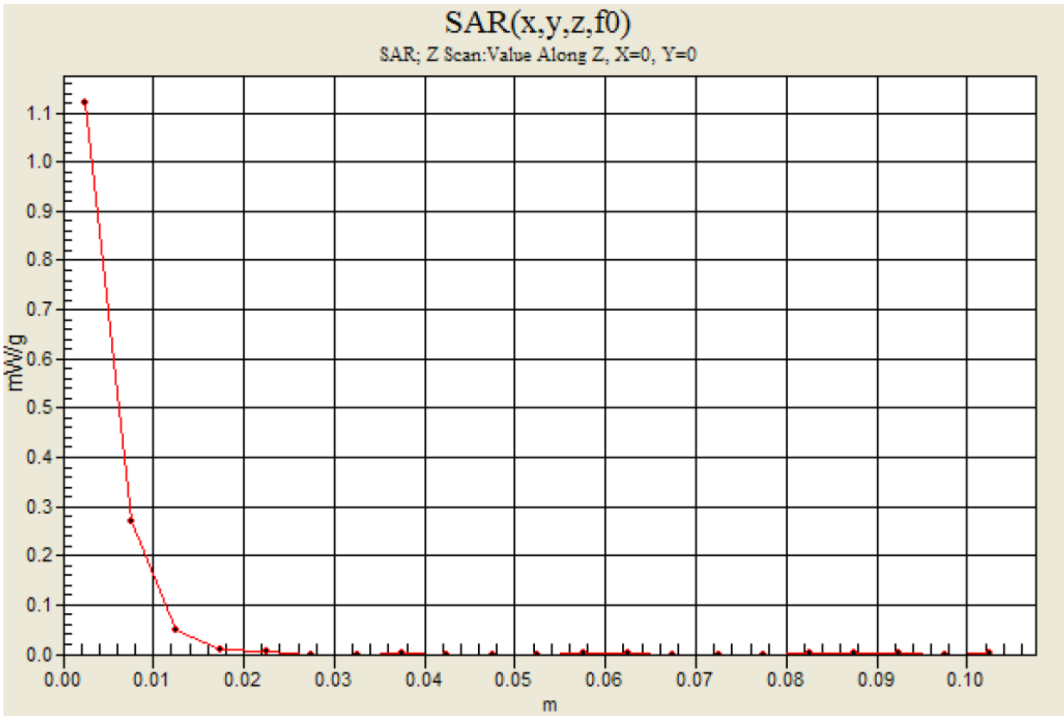
Date/Time: 11/16/2011 5:18:18 PM

Test Laboratory: UL CCS SAR Lab D

5GHz_Body

Communication System: 802.11abgn; Frequency: 5600 MHz; Duty Cycle: 1:1

Edge 2_ Ch120/Z Scan (1x1x21): Measurement grid: dx=20mm, dy=20mm, dz=5mm
Maximum value of SAR (measured) = 1.12 mW/g



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Test Laboratory: UL CCS SAR Lab D

5GHz_Body

DUT: Apple; Type: 17 inch; Serial: N/A

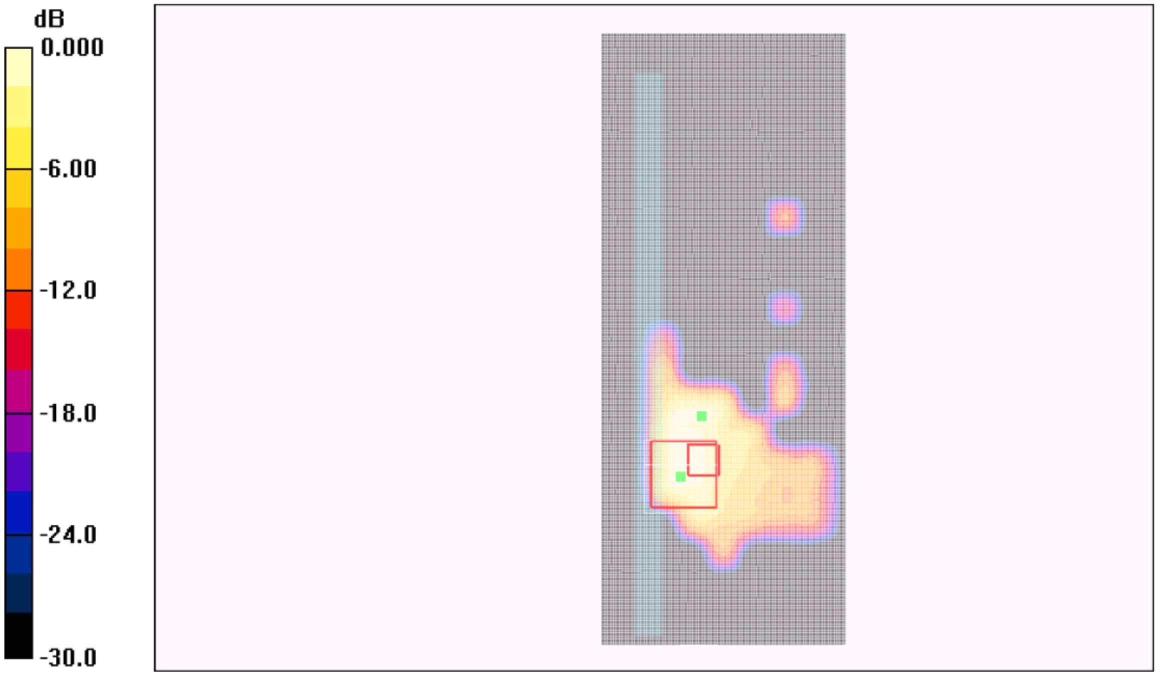
Communication System: 802.11abgn; Frequency: 5785 MHz; Duty Cycle: 1:1
Medium parameters used: f = 5785 MHz; σ = 5.79 mho/m; ε_r = 50.4; ρ = 1000 kg/m^3
Phantom section: Flat Section

Room Ambient Temperature: 25.0 deg. C; Liquid Temperature: 24.0 deg. C

DASY4 Configuration:
- Area Scan setting - Find Secondary Maximum Within: 2.0 dB and with a peak SAR value greater than 0.0012W/kg
- Probe: EX3DV4 - SN3686; ConvF(3.7, 3.7, 3.7); Calibrated: 1/24/2011
- Sensor-Surface: 2.5mm (Mechanical Surface Detection (Locations From Previous Scan Used))Sensor-Surface: 2.5mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1259; Calibrated: 5/3/2011
- Phantom: Flat Phantom ELI4.0; Type: QDOVA001BB; Serial: SN:1017
- Measurement SW: DASY4, V4.7 Build 80; Post processing SW: SEMCAD, V1.8 Build 186

Edge 2_ Ch157/Area Scan (81x201x1): Measurement grid: dx=10mm, dy=10mm
Maximum value of SAR (interpolated) = 1.10 mW/g

Edge 2_ Ch157/Zoom Scan (7x7x9)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=2.5mm
Reference Value = 14.3 V/m; Power Drift = 0.047 dB
Peak SAR (extrapolated) = 5.74 W/kg
SAR(1 g) = 0.581 mW/g; SAR(10 g) = 0.217 mW/g
Maximum value of SAR (measured) = 1.22 mW/g



0 dB = 1.22mW/g

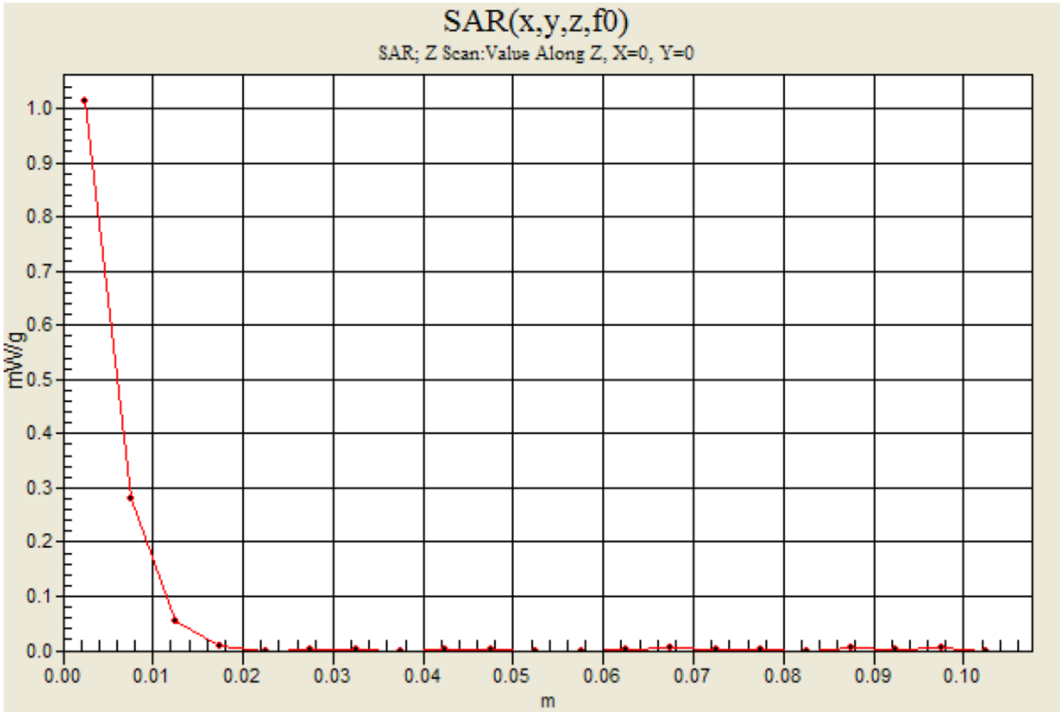
Date/Time: 11/16/2011 3:57:31 PM

Test Laboratory: UL CCS SAR Lab D

5GHz_Body

Communication System: 802.11abgn; Frequency: 5785 MHz; Duty Cycle: 1:1

Edge 2_ Ch157/Z Scan (1x1x21): Measurement grid: dx=20mm, dy=20mm, dz=5mm
Maximum value of SAR (measured) = 1.01 mW/g



15. Appendixes

Refer to individual files for the following appendixes:

15.1. System Performance Check Plots

15.2. SAR Test Plots for 2.4GHz

15.3. SAR Test Plots for 5GHz Bands

15.4. Calibration Certificate for E-field Probe EX3DV4 - SN 3686

15.5. Calibration Certificate for D2450V2 SN 706(w/ ext. cal. data)

15.6. Calibration Certificate for D5GHzV2 - SN 1003