SAR EVALUATION REPORT

FCC 47 CFR § 2.1093
IEEE Std 1528-2013

For
802.11a/g/n/ac 3X3 WLAN + Bluetooth PCI-E Custom Combination Card

FCC ID: QDS-BRCM1088
Model Name: BCM943602BAED

Report Number: 15U20284-S1C
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Prepared for
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NVLAP LAB CODE 200065-0

Revision History

Rev.	Date	Revisions	Revised By
--	6/5/2015	Initial Issue	--
A	6/15/2015	Report revised based on Reviewer's comments: 1. Sec. 12: Updated	Kenneth Mak
B	6/18/2015	Updated Section 12 for clarity	Dave Weaver
C	6/23/2015	Section 12 – changed calculated SPLSR decimal places to agree with KDB 447498. Corrected < to ≤ for SPLSR conclusions	Dave Weaver

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1. Attestation of Test Results

Applicant Name	BROADCOM CORPORATION			
FCC ID	QDS-BRCM1088			
Model Name	BCM943602BAED			
Applicable Standards	FCC 47 CFR § 2.1093 Published RF exposure KDB procedures IEEE Std 1528-2013			
SAR Limits (W/Kg)				
Exposure Category	Peak spatial-average(1g of tissue)			
General population / Uncontrolled exposure	1.6			
The Highest Reported SAR (W/kg)				
RF Exposure Conditions	**Equipment Class**			
	Licensed	**DTS**	**U-NII**	**DSS**
Standalone	N/A	0.765	0.656	0.131
Simultaneous Transmission	N/A	0.765	0.787	0.787
Date Tested	5/11/2015 to 5/20/2015			
Test Results	Pass			

UL Verification Services Inc. 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 Verification Services Inc. 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 Verification Services Inc. and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL Verification Services Inc. 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.

Approved & Released By:	Prepared By:
	
David Weaver Program Manager UL Verification Services Inc.	James Kim Laboratory Technician UL Verification Services Inc.

2. Test Specification, Methods and Procedures

The tests documented in this report were performed in accordance with FCC 47 CFR § 2.1093, IEEE STD 1528-2013, the following FCC Published RF exposure KDB procedures:

- 248227 D01 802.11 Wi-Fi SAR v02
- 447498 D01 General RF Exposure Guidance v05r02
- 447498 D03 Supplement C Cross-Reference v01
- 616217 D04 SAR for laptop and tablets v01r01
- 690783 D01 SAR Listings on Grants v01r03
- 865664 D01 SAR measurement 100 MHz to 6 GHz v01r03
- 865664 D02 RF Exposure Reporting v01r01

3. Facilities and Accreditation

The test sites and measurement facilities used to collect data are located at

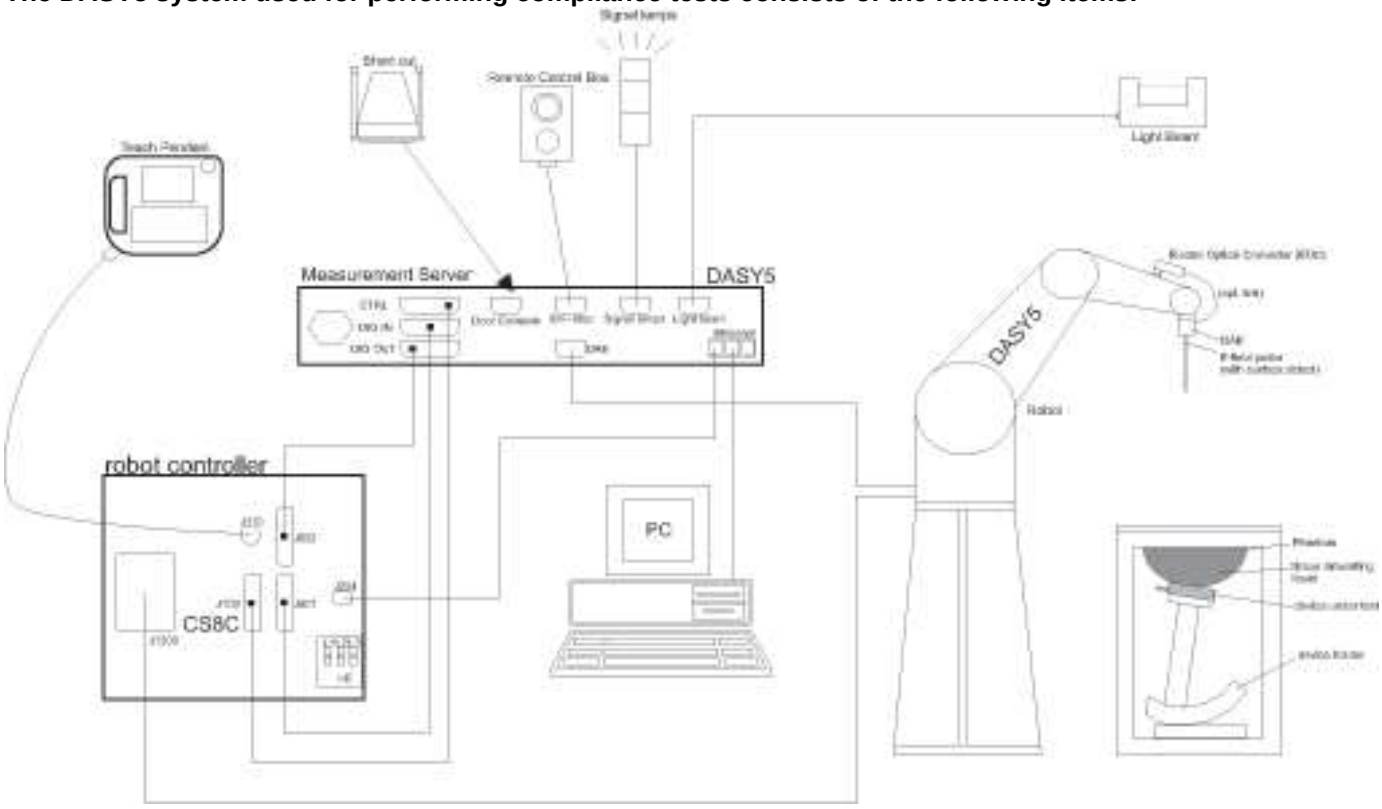
47173 Benicia Street	47266 Benicia Street
SAR Lab A	SAR Lab 1
SAR Lab B	SAR Lab 2
SAR Lab C	SAR Lab 3
SAR Lab D	SAR Lab 4
SAR Lab E	SAR Lab 5
SAR Lab F	
SAR Lab G	
SAR Lab H	

UL Verification Services Inc. is accredited by NVLAP, Laboratory Code 200065-0.

4. SAR Measurement System & Test Equipment

4.1. SAR Measurement System

The DASY5 system used for performing compliance tests consists of the following items:



- A standard high precision 6-axis robot with controller, teach pendant and software. An arm extension for accommodating the data acquisition electronics (DAE).
- An isotropic Field probe optimized and calibrated for the targeted measurement.
- 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 Electro-optical converter (EOC) performs the conversion from optical to electrical signals for the digital communication to the DAE. To use optical surface detection, a special version of the EOC is required. The EOC signal is transmitted to the measurement server.
- 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.
- The Light Beam used is for probe alignment. This improves the (absolute) accuracy of the probe positioning.
- A computer running WinXP or Win7 and the DASY5 software.
- Remote control and teach pendant as well as additional circuitry for robot safety such as warning lamps, etc.
- The phantom, the device holder and other accessories according to the targeted measurement.

4.2. SAR 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.

Area Scan Parameters extracted from KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz

	≤ 3 GHz	> 3 GHz
Maximum distance from closest measurement point (geometric center of probe sensors) to phantom surface	5 ± 1 mm	½·δ·ln(2) ± 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.	

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 points (refer to table below) 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.

Zoom Scan Parameters extracted from KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz

			≤ 3 GHz	> 3 GHz
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	≤ 1.5·$\Delta z_{Zoom}(n-1)$	
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.

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 (FCC only)

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.

4.3. Test Equipment

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

Dielectric Property Measurements

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Network Analyzer	Agilent	8753ES	MY40001647	7/17/2015
Dielectric Probe kit	SPEAG	DAK-3.5	1087	11/11/2015
Shorting block	SPEAG	DAK-3.5 Short	SM DAK 200 BA	N/A
Thermometer	Traceable Calibration Control Co.	4242	122529162	10/8/2015

System Check

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Synthesized Signal Generator	HP	8665B	3744A01155	3/18/2016
Power Meter	HP	437B	3125U11364	8/27/2015
Power Meter	HP	437B	3125U12345	8/15/2015
Power Sensor	HP	8481A	1926A27048	8/15/2015
Power Sensor	HP	8481A	2702A76223	9/17/2015
Amplifier	MITEQ	AMF-4D-00400600-50-30P	1795092	N/A
Directional coupler	Werlatone	C8060-102	2141	N/A
DC Power Supply	BK PRECISION	1611	215-02292	N/A
E-Field Probe (SAR Lab E)	SPEAG	EX3DV4	3772	2/23/2016
E-Field Probe (SAR Lab G)	SPEAG	EX3DV4	3686	2/23/2016
Data Acquisition Electronics (SAR Lab E)	SPEAG	DAE4	1257	9/29/2015
Data Acquisition Electronics (SAR Lab G)	SPEAG	DAE4	1433	3/12/2016
System Validation Dipole	SPEAG	D2450V2	899	3/13/2016
System Validation Dipole	SPEAG	D2450V2	706	5/20/2015
System Validation Dipole	SPEAG	D5GHzV2	1003	2/20/2016

Other

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Power Meter	Agilent	N1911A	MY53060016	8/7/2015
Power Sensor	Agilent	N1921A	MY52020022	12/12/2015

5. Measurement Uncertainty

Per KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz, when the highest measured 1-g SAR within a frequency band is < 1.5 W/kg, the extensive SAR measurement uncertainty analysis described in IEEE Std 1528-2013 is not required in SAR reports submitted for equipment approval.

6. Device Under Test (DUT) Information

6.1. DUT Description

Antenna tested Chain 0	Manufacturer	Antenna type	Part number
	Amphenol/Molex	802.11abgn WLAN Antenna	WF2(604-7575)
	Peak Gain: 3.33dBi (2.4GHz); 5.85dBi (5.2GHz), 6.21dBi (5.5-5.8GHz)		
	Cable 50 ohm Coaxial, length: 199 mm		

6.2. Wireless Technologies

Wireless technologies	Frequency bands	Operating mode	Duty Cycle used for SAR testing
Wi-Fi	2.4 GHz	802.11b 802.11g 802.11n (HT20) 802.11n (HT40)	100%
	5 GHz	802.11a 802.11n (HT20) 802.11n (HT40) 802.11ac (VHT20) 802.11ac (VHT40) 802.11ac (VHT80)	100%
Bluetooth	2.4 GHz	Version 4.1 LE	77.5% (DH5)

6.3. Testing Rationale

All SAR testing was performed using chain 0 and was judged to be representative of chain 1 and chain 2 as the transmitters are identically implemented.

Test selection was performed in accordance with 248227 D01 802.11 Wi-Fi SAR v02

The standalone (SISO) SAR results were considered acceptable for the MIMO simultaneous transmission analysis as the MIMO power does not exceed the SISO power.

The antenna separation distance will not be less than 50mm.

Supported Simultaneous Scenarios

Band	WLAN			Bluetooth
	Chain 0	Chain 1	Chain 2	Chain 0
2.4 GHz	✓	✓	✓	
		✓	✓	✓
5 GHz	✓	✓	✓	✓

6.4. Nominal and Maximum Output Power

KDB 447498 sec.4.1.(3) at the maximum rated output power and within the tune-up tolerance range specified for the product, but not more than 2 dB lower than the maximum tune-up tolerance limit

Upper limit (dB): -1.5 ~ 1.0		Max. RF Output Power (dBm)	
RF Air interface	Mode	Target	Max. tune-up tolerance limit
WiFi 2.4 GHz	802.11b	13.75	**14.75**
	802.11g	13.75	**14.75**
	802.11n HT20	13.75	**14.75**
	802.11n HT40	13.75	**14.75**
WiFi 5.2 & 5.3 GHz	802.11a	12.25	**13.25**
	802.11n HT20	12.25	**13.25**
	802.11n HT40	12.25	**13.25**
	802.11ac VHT20	12.25	**13.25**
	802.11ac VHT40	12.25	**13.25**
	802.11ac VHT80	12.25	**13.25**
WiFi 5.5 GHz	802.11a	11.00	**12.00**
	802.11n HT20	11.00	**12.00**
	802.11n HT40	11.00	**12.00**
	802.11ac VHT20	11.00	**12.00**
	802.11ac VHT40	11.00	**12.00**
	802.11ac VHT80	11.00	**12.00**
WiFi 5.8 GHz	802.11a	12.00	**13.00**
	802.11n HT20	12.00	**13.00**
	802.11n HT40	12.00	**13.00**
	802.11ac VHT20	12.00	**13.00**
	802.11ac VHT40	12.00	**13.00**
	802.11ac VHT80	12.00	**13.00**
Bluetooth		6.50	**7.50**
Bluetooth LE		2.50	**3.50**

7. RF Exposure Conditions (Test Configurations)

Refer to “SAR Photos and Ant locations” Appendix for the specific details of the antenna-to-antenna and antenna-to-edge(s) distances.

Wireless technologies	RF Exposure Conditions	DUT-to-User Separation	Test Position	Antenna-to-edge/surface	SAR Required	Note
WLAN	Standalone	5 mm	Rear	5 mm	Yes	
			Front	5 mm	Yes	
			Edge 1 (Top)	5 mm	Yes	
			Edge 2 (Right)	5 mm	Yes	
			Edge 3 (Bottom)	5 mm	Yes	
			Edge 4 (Left)	5 mm	Yes	

8. Dielectric Property Measurements & System Check

8.1. Dielectric Property Measurements

The temperature of the tissue-equivalent medium used during measurement must also be within 18°C to 25°C and within ± 2°C of the temperature when the tissue parameters are characterized.

The dielectric parameters must be measured before the tissue-equivalent medium is used in a series of SAR measurements. The parameters should be re-measured after each 3 – 4 days of use; or earlier if the dielectric parameters can become out of tolerance; for example, when the parameters are marginal at the beginning of the measurement series.

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

Tissue Dielectric Parameters

FCC KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz

Target Frequency (MHz)	Head		Body	
	ε_r	σ (S/m)	ε_r	σ (S/m)
150	52.3	0.76	61.9	0.80
300	45.3	0.87	58.2	0.92
450	43.5	0.87	56.7	0.94
835	41.5	0.90	55.2	0.97
900	41.5	0.97	55.0	1.05
915	41.5	0.98	55.0	1.06
1450	40.5	1.20	54.0	1.30
1610	40.3	1.29	53.8	1.40
1800 – 2000	40.0	1.40	53.3	1.52
2450	39.2	1.80	52.7	1.95
3000	38.5	2.40	52.0	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

IEEE Std 1528-2013

Refer to Table 3 within the IEEE Std 1528-2013

Dielectric Property Measurements Results:

SAR Lab E

Date	Freq. (MHz)	Liquid Parameters			Measured	Target	Delta (%)	Limit ±(%)
5/11/2015	Body 5180	e'	48.1900	Relative Permittivity (ϵ_r):	48.19	49.05	-1.75	5
		e''	18.4400	Conductivity (σ):	5.31	5.27	0.75	5
	Body 5200	e'	48.1500	Relative Permittivity (ϵ_r):	48.15	49.02	-1.77	5
		e''	18.4200	Conductivity (σ):	5.33	5.29	0.59	5
	Body 5600	e'	47.3200	Relative Permittivity (ϵ_r):	47.32	48.48	-2.39	5
		e''	18.7400	Conductivity (σ):	5.84	5.76	1.29	5
	Body 5800	e'	47.0900	Relative Permittivity (ϵ_r):	47.09	48.20	-2.30	5
		e''	18.8700	Conductivity (σ):	6.09	6.00	1.43	5
	Body 5825	e'	47.0500	Relative Permittivity (ϵ_r):	47.05	48.20	-2.39	5
		e''	18.9000	Conductivity (σ):	6.12	6.00	2.02	5

SAR Lab G

Date	Freq. (MHz)	Liquid Parameters			Measured	Target	Delta (%)	Limit ±(%)
5/5/2015	Body 2450	e'	52.0000	Relative Permittivity (ϵ_r):	52.00	52.70	-1.33	5
		e''	14.8700	Conductivity (σ):	2.03	1.95	3.88	5
	Body 2410	e'	52.1200	Relative Permittivity (ϵ_r):	52.12	52.76	-1.21	5
		e''	14.7000	Conductivity (σ):	1.97	1.91	3.27	5
	Body 2475	e'	51.9900	Relative Permittivity (ϵ_r):	51.99	52.67	-1.29	5
		e''	14.9800	Conductivity (σ):	2.06	1.99	3.85	5
5/19/2015	Body 2450	e'	51.8500	Relative Permittivity (ϵ_r):	51.85	52.70	-1.61	5
		e''	14.3700	Conductivity (σ):	1.96	1.95	0.39	5
	Body 2410	e'	52.0400	Relative Permittivity (ϵ_r):	52.04	52.76	-1.36	5
		e''	14.1600	Conductivity (σ):	1.90	1.91	-0.52	5
	Body 2475	e'	51.7300	Relative Permittivity (ϵ_r):	51.73	52.67	-1.78	5
		e''	14.4500	Conductivity (σ):	1.99	1.99	0.17	5

8.2. System Check

SAR system verification is required to confirm measurement accuracy, according to the tissue dielectric media, probe calibration points and other system operating parameters required for measuring the SAR of a test device. The system verification must be performed for each frequency band and within the valid range of each probe calibration point required for testing the device. The same SAR probe(s) and tissue-equivalent media combinations used with each specific SAR system for system verification must be used for device testing. When multiple probe calibration points are required to cover substantially large transmission bands, independent system verifications are required for each probe calibration point. A system verification must be performed before each series of SAR measurements using the same probe calibration point and tissue-equivalent medium. Additional system verification should be considered according to the conditions of the tissue-equivalent medium and measured tissue dielectric parameters, typically every three to four days when the liquid parameters are re-measured or sooner when marginal liquid parameters are used at the beginning of a series of measurements.

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 depth of tissue-equivalent liquid in a phantom must be ≥ 15.0 cm for SAR measurements ≤ 3 GHz and ≥ 10.0 cm for measurements > 3 GHz.
- 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 (below 3 GHz) and/or 8x8x7 (above 3 GHz) fine cube was chosen for the 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.

Reference Target SAR Values

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

System Dipole	Serial No.	Cal. Date	Freq. (MHz)	Target SAR Values (W/kg)		
				1g/10g	Head	Body
D2450V2	706	5/20/2014	2450	1g	53.0	50.2
				10g	24.5	23.4
D2450V2	899	3/13/2015	2450	1g	51.6	48.8
				10g	23.9	22.7
D5GHzV2	1003	2/20/2015	5200	1g	76.4	72.7
				10g	21.9	20.4
			5600	1g	79.6	77.0
				10g	22.8	21.3
			5800	1g	76.1	75.0
				10g	21.7	20.6

System Check Results

The 1-g and 10-g SAR measured with a reference dipole, using the required tissue-equivalent medium at the test frequency, must be within 10% of the manufacturer calibrated dipole SAR target.

SAR Lab E

Date Tested	System Dipole		T.S. Liquid		Measured Results		Target (Ref. Value)	Delta ±10 %	Plot No.
	Type	Serial #			Zoom Scan to 100 mW	Normalize to 1 W			
5/11/2015	D5GHzV2 (5.2GHz)	1003	Body	1g	7.62	76.2	72.7	4.81	1,2
				10g	2.17	21.7	20.4	6.37	
5/11/2015	D5GHzV2 (5.6GHz)	1003	Body	1g	7.88	78.8	77.0	2.34	
				10g	2.22	22.2	21.3	4.23	
5/11/2015	D5GHzV2 (5.8GHz)	1003	Body	1g	7.60	76.0	75.0	1.33	
				10g	2.14	21.4	20.6	3.88	

SAR Lab G

Date Tested	System Dipole		T.S. Liquid		Measured Results		Target (Ref. Value)	Delta ±10 %	Plot No.
	Type	Serial #			Zoom Scan to 100 mW	Normalize to 1 W			
5/5/2015	D2450V2	706	Body	1g	5.35	53.5	50.2	6.57	3,4
				10g	2.48	24.8	23.4	5.98	
5/19/2015	D2450V2	899	Body	1g	5.14	51.4	48.8	5.33	5,6
				10g	2.36	23.6	22.7	3.96	

9. Conducted Output Power Measurements

9.1. Wi-Fi 2.4GHz (DTS Band)

Measured Results

Band (GHz)	Mode	Data Rate	Ch #	Freq. (MHz)	Avg Pwr (dBm)	Max Output Power (dBm)	SAR Test (Yes/No)	Note(s)
2.4	802.11b	1 Mbps	1	2412	14.7	**14.75**	Yes	
			6	**2437**	**14.7**			
			11	2462	14.7			
	802.11g	6 Mbps	1	2412	Not Required	14.75	No	1
			6	2437				
			11	2462				
	802.11n (HT20)	6.5 Mbps	1	2412		14.75	No	1
			6	2437				
			11	2462				
	802.11n (HT40)	13.5 Mbps	3	2422		14.75	No	1
			6	2437				
			9	2452				

Note(s):

1. Output Power and SAR is not required for 802.11g/n HT20/HT40 channels when the highest *reported* SAR for DSSS is adjusted by the ratio of OFDM to DSSS specified maximum output power and the adjusted SAR is ≤ 1.2 W/kg.

9.2. Wi-Fi 5GHz (U-NII Bands)

Measured Results

Band (GHz)	Mode	Data Rate	Ch #	Freq. (MHz)	Avg Pwr (dBm)	Max Output Power (dBm)	SAR Test (Yes/No)
5.2 (U-NII 1)	802.11a	6 Mbps	36	5180	Not Required	13.25	No
			40	5200			
			44	5220			
			48	5240			
	802.11n (HT20)	6.5 Mbps	36	5180		13.25	No
			40	5200			
			44	5220			
			48	5240			
	802.11n (HT40)	13.5 Mbps	38	5190		13.25	No
			46	5230			
	802.11ac (VHT20)	6.5 Mbps	36	5180		13.25	No
			40	5200			
			44	5220			
			48	5240			
	802.11ac (VHT40)	13.5 Mbps	38	5190		13.25	No
			46	5230			
	802.11ac (VHT80)	29.3 Mbps	42	5210	13.25	13.25	No
5.3 UNII-2A	802.11a	6 Mbps	52	5260	Not Required	13.25	No
			56	5280			
			60	5300			
			64	5320			
	802.11n (HT20)	6.5 Mbps	52	5260		13.25	No
			56	5280			
			60	5300			
			64	5320			
	802.11n (HT40)	13.5 Mbps	54	5270		13.25	No
			62	5310			
	802.11ac (VHT20)	6.5 Mbps	52	5260		13.25	No
			56	5280			
			60	5300			
			64	5320			
	802.11ac (VHT40)	13.5 Mbps	54	5270		13.25	No
			62	5310			
	802.11ac (VHT80)	29.3 Mbps	58	5290	13.25	13.25	Yes

Band (GHz)	Mode	Data Rate	Ch #	Freq. (MHz)	Avg Pwr (dBm)	Max Output Power (dBm)	SAR Test (Yes/No)
5.5 UNII-2C	802.11a	6 Mbps	100	5500	Not Required	12.0	No
			116	5580			
			124	5620			
			140	5700			
	802.11n (HT20)	6.5 Mbps	100	5500		12.0	No
			116	5580			
			124	5620			
			140	5700			
	802.11n (HT40)	13.5 Mbps	102	5510		12.0	No
			118	5590			
			134	5670			
	802.11ac (VHT20)	6.5 Mbps	100	5500		12.0	No
			116	5580			
			124	5620			
			140	5700			
	802.11ac (VHT40)	13.5 Mbps	102	5510		12.0	No
			118	5590			
			134	5670			
	802.11ac (VHT80)	29.3 Mbps	106	5530	12.0	12.0	Yes
			122	5610	11.7		
			138	5690	11.7		
5.8 UNII-3 or §15.247	802.11a	6 Mbps	149	5745	Not Required	13.0	No
			157	5785			
			165	5825			
	802.11n (HT20)	6.5 Mbps	149	5745		13.0	No
			157	5785			
			165	5825			
	802.11n (HT40)	13.5 Mbps	151	5755		13.0	No
			159	5795			
	802.11ac (VHT20)	6.5 Mbps	149	5745		13.0	No
			157	5785			
			165	5825			
	802.11ac (VHT40)	13.5 Mbps	151	5755		13.0	No
			159	5795			
	802.11ac (VHT80)	29.3 Mbps	155	5775	12.9	13.0	Yes

Note(s):

1. Output Power and SAR measurement is not required for 802.11a/n/ac VHT20/VHT40 channels when the specified tune-up tolerances for 802.11a/n/ac VHT20/VHT40 are lower than 802.11ac VHT80 by more than ½ dB and the measured SAR is ≤ 1.2 W/Kg.
2. When the same transmission mode configurations have the same maximum output power on the same channel for the 802.11 a/g/n/ac modes, the channel with the largest bandwidth and lowest data rate is selected (i.e. 802.11ac VHT80).
3. When the specified maximum output power is the same for both UNII band I and UNII band 2A, begin SAR measurement in UNII band 2A; and if the highest *reported* SAR for UNII band 2A is
   - ≤ 1.2 W/kg, SAR is not required for UNII band I
   - > 1.2 W/kg, both bands should be tested independently for SAR.

9.3. Bluetooth

Band (GHz)	Mode	Ch #	Freq. (MHz)	Avg Pwr (dBm)	Avg Pwr (mW)
2.4	V3.0 + BDR, GFSK	0	2402	7.1	5.13
		39	2441	7.2	5.25
		78	2480	7.0	5.01
	V3.0 + EDR, 8-DPSK	0	2402	3.0	2.00
		39	2441	3.1	2.04
		78	2480	3.0	1.97
	V4.0 LE, GFSK	0	2402	3.2	2.08
		19	2440	3.2	2.07
		39	2480	2.1	1.61

10. Measured and Reported (Scaled) SAR Results

SAR Test Reduction criteria are as follows:

KDB 447498 D01 General RF Exposure Guidance:

Testing of other required channels within the operating mode of a frequency band is not required when the reported 1-g or 10-g SAR for the mid-band or highest output power channel is:

- ≤ 0.8 W/kg or 2.0 W/kg, for 1-g or 10-g respectively, when the transmission band is ≤ 100 MHz
- ≤ 0.6 W/kg or 1.5 W/kg, for 1-g or 10-g respectively, when the transmission band is between 100 MHz and 200 MHz
- ≤ 0.4 W/kg or 1.0 W/kg, for 1-g or 10-g respectively, when the transmission band is ≥ 200 MHz

KDB 248227 D01 SAR meas for 802.11 v02:

SAR test reduction for 802.11 Wi-Fi transmission mode configurations are considered separately for DSSS and OFDM. An initial test position is determined to reduce the number of tests required for certain exposure configurations with multiple test positions. An initial test configuration is determined for each frequency band and aggregated band according to maximum output power, channel bandwidth, wireless mode configurations and other operating parameters to streamline the measurement requirements. For 2.4 GHz DSSS, either the initial test position or DSSS procedure is applied to reduce the number of SAR tests; these are mutually exclusive. For OFDM, an initial test position is only applicable to next to the ear, UMPC mini-tablet and hotspot mode configurations, which is tested using the initial test configuration to facilitate test reduction. For other exposure conditions with a fixed test position, SAR test reduction is determined using only the initial test configuration.

The multiple test positions require SAR measurements in head, hotspot mode or UMPC mini-tablet configurations may be reduced according to the highest reported SAR determined using the *initial test position(s)* by applying the DSSS or OFDM SAR measurement procedures in the required wireless mode test configuration(s). The *initial test position(s)* is measured using the highest measured maximum output power channel in the required wireless mode test configuration(s). When the *reported* SAR for the *initial test position* is:

- ≤ 0.4 W/kg, further SAR measurement is not required for the other test positions in that exposure configuration and wireless mode combination within the frequency band or aggregated band. DSSS and OFDM configurations are considered separately according to the required SAR procedures.
- > 0.4 W/kg, SAR is repeated using the same wireless mode test configuration tested in the *initial test position* to measure the subsequent next closet/smallest test separation distance and maximum coupling test position, on the highest maximum output power channel, until the *reported* SAR is ≤ 0.8 W/kg or all required test positions are tested.
  - For subsequent test positions with equivalent test separation distance or when exposure is dominated by coupling conditions, the position for maximum coupling condition should be tested.
  - When it is unclear, all equivalent conditions must be tested.
- For all positions/configurations tested using the *initial test position* and subsequent test positions, when the *reported* SAR is > 0.8 W/kg, measure the SAR for these positions/configurations on the subsequent next highest measured output power channel(s) until the *reported* SAR is ≤ 1.2 W/kg or all required test channels are considered.
  - The additional power measurements required for this step should be limited to those necessary for identifying subsequent highest output power channels to apply the test reduction.
- When the specified maximum output power is the same for both UNII 1 and UNII 2A, begin SAR measurements in UNII 2A with the channel with the highest measured output power. If the reported SAR for UNII 2A is ≤ 1.2 W/kg, SAR is not required for UNII 1; otherwise treat the remaining bands separately and test them independently for SAR.
- When the specified maximum output power is different between UNII 1 and UNII 2A, begin SAR with the band that has the higher specified maximum output. If the highest reported SAR for the band with the highest specified power is ≤ 1.2 W/kg, testing for the band with the lower specified output power is not required; otherwise test the remaining bands independently for SAR.

To determine the *initial test position*, Area Scans were performed to determine the position with the *Maximum Value of SAR (measured)*. The position that produced the highest *Maximum Value of SAR* is considered the worst case position; thus used as the *initial test position*.

10.1. Wi-Fi (DTS Band)

Frequency Band	Mode	RF Exposure Conditions	Dist. (mm)	Test Position	Ch #.	Freq. (MHz)	Area Scan Max. SAR (W/kg)	Power (dBm)		1-g SAR (W/kg)		Notes	Plot No.
								Tune-up limit	Meas.	Meas.	Scaled		
2.4GHz	802.11b 1 Mbps	Standalone	5	Rear	6	2437.0	1.000	14.75	14.70	0.756	**0.765**	2	1
				Front	6	2437.0	0.897	14.75	14.70	0.699	0.707		
				Edge 1	6	2437.0	0.665	14.75	14.70				
				Edge 2	6	2437.0	0.096	14.75	14.70				
				Edge 3	6	2437.0	0.017	14.75	14.70				
				Edge 4	6	2437.0	0.036	14.75	14.70				

Note(s):

1. Highest *reported* SAR is ≤ 0.4 W/kg. Therefore, further SAR measurements within this exposure condition are not required.
2. Highest *reported* SAR is > 0.4 W/kg. Due to the highest *reported* SAR for this test position, other test positions in Head exposure condition were evaluated until a SAR ≤ 0.8 W/kg was *reported*.

10.2. Wi-Fi (U-NII Band)

Frequency Band	Mode	RF Exposure Conditions	Dist. (mm)	Test Position	Ch #.	Freq. (MHz)	Area Scan Max. SAR (W/kg)	Power (dBm)		1-g SAR (W/kg)		Notes	Plot No.
								Tune-up limit	Meas.	Meas.	Scaled		
5.3GHz	802.11ac VHT80	Standalone	5	Rear	58	5290.0	1.060	13.25	13.25	0.644	0.644		
				Front	58	5290.0	1.300	13.25	13.25	0.651	0.651	2	2
				Edge 1	58	5290.0	0.599	13.25	13.25				
				Edge 2	58	5290.0	0.236	13.25	13.25				
				Edge 3	58	5290.0	0.128	13.25	13.25				
				Edge 4	58	5290.0	0.185	13.25	13.25				
Frequency Band	Mode	RF Exposure Conditions	Dist. (mm)	Test Position	Ch #.	Freq. (MHz)	Area Scan Max. SAR (W/kg)	Power (dBm)		1-g SAR (W/kg)		Notes	Plot No.
								Tune-up limit	Meas.	Meas.	Scaled		
5.5GHz	802.11ac VHT80	Standalone	5	Rear	106	5530.0	1.160	12.0	12.0	0.656	**0.656**		3
				Front	106	5530.0	0.883	12.0	12.0	0.554	0.554	2	
				Edge 1	106	5530.0	0.625	12.0	12.0				
				Edge 2	106	5530.0	0.191	12.0	12.0				
				Edge 3	106	5530.0	0.161	12.0	12.0				
				Edge 4	106	5530.0	0.208	12.0	12.0				
Frequency Band	Mode	RF Exposure Conditions	Dist. (mm)	Test Position	Ch #.	Freq. (MHz)	Area Scan Max. SAR (W/kg)	Power (dBm)		1-g SAR (W/kg)		Notes	Plot No.
								Tune-up limit	Meas.	Meas.	Scaled		
5.8GHz	802.11ac VHT80	Standalone	5	Rear	155	5775.0	1.180	13.0	12.9	0.641	**0.656**		4
				Front	155	5775.0	0.880	13.0	12.9	0.460	0.471	2	
				Edge 1	155	5775.0	0.495	13.0	12.9				
				Edge 2	155	5775.0	0.178	13.0	12.9				
				Edge 3	155	5775.0	0.195	13.0	12.9				
				Edge 4	155	5775.0	0.205	13.0	12.9				

Note(s):

1. Highest *reported* SAR is ≤ 0.4 W/kg. Therefore, further SAR measurements within this exposure condition are not required.
2. Highest *reported* SAR is > 0.4 W/kg. Due to the highest *reported* SAR for this test position, other test positions in standalone exposure condition were evaluated until a SAR ≤ 0.8 W/kg was *reported*.

10.3. Bluetooth

Frequency Band	Mode	RF Exposure Condition	Dist. (mm)	Test Position	Ch #.	Freq. (MHz)	Area Scan Max. SAR (W/kg)	Power (dBm)		1-g SAR (W/kg)		Notes	Plot No.
								Tune-up limit	Meas.	Meas.	Scaled		
2.4 GHz	GFSK	Standalone	5	Rear	39	2441.0	0.175	7.5	7.2	0.122	**0.131**	1	5
				Front	39	2441.0	0.133	7.5	7.2				
				Edge 1	39	2441.0	0.066	7.5	7.2				
				Edge 2	39	2441.0	0.012	7.5	7.2				
				Edge 3	39	2441.0	0.001	7.5	7.2				
				Edge 4	39	2441.0	0.004	7.5	7.2				

Note(s):

1. Highest *reported* SAR is ≤ 0.4 W/kg. Therefore, further SAR measurements within this exposure condition are not required.

10.4. Enhanced Energy Coupling

Enhanced Energy Coupling evaluation is not required according to KDB 447498 §5.2.4 as the highest measured SAR is >0.4W/kg

11. SAR Measurement Variability

In accordance with published RF Exposure KDB 865664 D01 SAR measurement 100 MHz to 6 GHz. These additional measurements are repeated after the completion of all measurements requiring the same head or body tissue-equivalent medium in a frequency band. The test device should be returned to ambient conditions (normal room temperature) with the battery fully charged before it is re-mounted on the device holder for the repeated measurement(s) to minimize any unexpected variations in the repeated results.

1) Repeated measurement is not required when the original highest measured SAR is < 0.80 W/kg; steps 2) through 4) do not apply.
2) When the original highest measured SAR is ≥ 0.80 W/kg, repeat that measurement once.
3) Perform a second repeated measurement only if the ratio of largest to smallest SAR for the original and first repeated measurements is > 1.20 or when the original or repeated measurement is ≥ 1.45 W/kg (~ 10% from the 1-g SAR limit).
4) Perform a third repeated measurement only if the original, first or second repeated measurement is ≥1.5 W/kg and the ratio of largest to smallest SAR for the original, first and second repeated measurements is > 1.20.

Frequency Band (MHz)	Air Interface	RF Exposure Conditions	Test Position	Repeated SAR (Yes/No)	Highest Measured SAR (W/kg)	Repeated Measured SAR (W/kg)	Largest to Smallest SAR Ratio
2400	Wi-Fi 802.11b/g/n	Standalone	Rear	No	0.756	N/A	N/A
	Bluetooth	Standalone	Rear	No	0.122	N/A	N/A
5300	Wi-Fi 802.11a/n/ac	Standalone	Front	No	0.651	N/A	N/A
5500	Wi-Fi 802.11a/n/ac	Standalone	Rear	No	0.656	N/A	N/A
5800	Wi-Fi 802.11a/n/ac	Standalone	Rear	No	0.641	N/A	N/A

Note(s):

Second Repeated Measurement is not required since the ratio of the largest to smallest SAR for the original and first repeated measurement is not > 1.20.

12. Simultaneous Transmission SAR Analysis

According to KDB 447498 D01 simultaneous SAR testing can be excluded under the following conditions:

The sum of the SAR for all simultaneously transmitting antennas is within the SAR limit.

If the sum of the SAR for all simultaneously transmitting antennas exceeds the SAR limit testing can still be excluded if the SAR to Peak Location Ratio (SPLSR) between any pair of simultaneously transmitting antennas is ≤0.04

$$SPLSR = (SAR_1 + SAR_2)^{1.5} / Ri$$

Where:

SAR_1 is the highest measured or estimated SAR for the first of a pair of simultaneous transmitting antennas, in a specific test operating mode and exposure condition

SAR_2 is the highest measured or estimated SAR for the second of a pair of simultaneous transmitting antennas, in the same test operating mode and exposure condition as the first

Ri is the separation distance between the pair of simultaneous transmitting antennas. When the SAR is measured, for both antennas in the pair, it is determined by the actual x, y and z coordinates in the 1-g SAR for each SAR peak location, based on the extrapolated and interpolated result in the zoom scan measurement, using the formula of $[(x_1-x_2)^2 + (y_1-y_2)^2 + (z_1-z_2)^2]$

Simultaneous Transmission Condition

RF Exposure Condition	Item	Capable Transmit Configurations						
Standalone	1	DTS	+	DTS	+	DTS		
	2	U-NII	+	U-NII	+	U-NII	+	BT
Notes:								
1. DTS Radio cannot transmit simultaneously with Bluetooth Radio.								
2. U-NII Radio can transmit simultaneously with Bluetooth Radio.								

12.1. Sum of SAR for worst case standalone measurements (Wi-Fi 2.4GHz)

3x3 MIMO is the worst case Simultaneous Transmission scenario.

RF Exposure conditions	① DTS	② DTS	③ DTS	①+②+③ DTS + DTS + DTS	
				∑ 1-g SAR	SPLSR (Yes/ No)
Rear	0.765	0.765	0.765	2.295	**Yes**
Front	0.707	0.707	0.707	2.121	**Yes**

Conclusion:

Where the ∑ 1-g SAR is less than 1.6 mW/g simultaneous transmission testing is not required
Where the ∑ 1-g SAR is greater than 1.6 mW/g SPLSR evaluation is required

SAR to Peak Location Separation Ratio (SPLSR)

Test Position	Worst-case combination			∑ 1-g SAR (mW/g)		Calculated distance (mm)	SPLSR (≤ 0.04)	Volume Scan (Yes/ No)	Figure
	① DTS	② DTS	③ DTS						
Rear	0.765	0.765		① + ②	1.530	50.0	0.04	No	
	0.765		0.765	① + ③	1.530	50.0	0.04	No	
		0.765	0.765	② + ③	1.530	50.0	0.04	No	
Front	0.707	0.707		① + ②	1.414	50.0	0.03	No	
	0.707		0.707	① + ③	1.414	50.0	0.03	No	
		0.707	0.707	② + ③	1.414	50.0	0.03	No	

Conclusion:

SPLSR is ≤ 0.04 therefore simultaneous transmission testing is not required

12.2. Sum of the SAR for Wi-Fi U-NII & BT

3x3 MIMO is the worst case Simultaneous Transmission scenario.

RF Exposure conditions	① U-NII	② U-NII	③ U-NII	④ BT	①+②+③+④ ∑U-NII + U-NII +U-NII +BT	
					∑1-g SAR (mW/g)	SPLSR (Yes/ No)
Rear	0.656	0.656	0.656	0.131	2.099	**Yes**
Front	0.651	0.651	0.651	0.131	2.084	**Yes**

Conclusion:

Where the ∑ 1-g SAR is less than 1.6 mW/g simultaneous transmission testing is not required
Where the ∑ 1-g SAR is greater than 1.6 mW/g SPLSR evaluation is required

SAR to Peak Location Separation Ratio (SPLSR)

Test Position	Worst-case combination			∑ 1-g SAR (mW/g)		Calculated distance (mm)	SPLSR (≤ 0.04)	Volume Scan (Yes/ No)	Figure
	① UNII + BT	② U-NII	③ UNII						
Rear	0.787	0.656		① + ②	1.443	50.0	0.03	No	
	0.787		0.656	① + ③	1.443	50.0	0.03	No	
		0.656	0.656	② + ③	1.312	50.0	0.03	No	
Front	0.782	0.651		① + ②	1.433	50.0	0.03	No	
	0.782		0.651	① + ③	1.433	50.0	0.03	No	
		0.651	0.651	② + ③	1.302	50.0	0.03	No	

Conclusion:

SPLSR is ≤ 0.04 therefore simultaneous transmission testing is not required

Appendixes

Refer to separated files for the following appendixes.

A_15U20284v0 SAR Photos & Ant. Locations

B_15U20284v0 SAR System Check Plots

C_15U20284v0 SAR Highest Test Plots

D_15U20284v0 SAR Tissue Ingredients

E_15U20284v0 SAR Probe Cal. Certificates

F_15U20284v0 SAR Dipole Cal. Certificates

END OF REPORT