Part 0: Qualcomm FastConnect WIFI TAS Characterization Report

For

Portable Computing Device with WLAN and Bluetooth

FCC ID: C3K2037
Model Name: 2037

Report Number: R14932101-S16
Issue Date: 4/24/2024

Prepared for

MICROSOFT CORP
1 MICROSOFT WAY
REDMOND, WA 98052-8300, U.S.

Prepared by

UL LLC
12 LABORATORY DR
RTP, NC 27709, U.S.A.
TEL: (510) 319-4000
FAX: (510) 661-0888

Revision History

Rev.	Date	Revisions	Revised By
V1	4/24/2024	Initial Issue	--

Table of Contents

1. Attestation of Test Results

Applicant Name	MICROSOFT CORP		
FCC ID	C3K2037		
Model Name	2037		
Reference SAR Report	R14932101-S8 (FCC) R14932101-S9 (ISED)		
Exposure Category	SAR Limits (W/Kg)		PD Limits (W/m^2)
	Peak Spatial Average (1-g of tissue)	Extremities (hands, wrists, ankles, etc.) (10-g of tissue)	
General Population (Uncontrolled Exposure)	1.6	4	10

UL LLC tested the above equipment in accordance with the requirements set forth in the above standards. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.
This report contains data provided by the customer which can impact the validity of results. UL LLC is only responsible for the validity of results after the integration of the data provided by the customer.
The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. It is the manufacturer's responsibility to assure that additional production units of this model are manufactured with identical electrical and mechanical components. All samples tested were in good operating condition throughout the entire test program. Measurement Uncertainties are published for informational purposes only and were not taken into account unless noted otherwise.
This document may not be altered or revised in any way unless done so by UL LLC and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL LLC 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 A2LA, NIST, or any agency of the U.S. Government, or any agency of the U.S. government.

Approved & Released By:	Prepared By:
	
Dave Weaver Senior Staff Engineer UL LLC	Richard Jankovics Staff Engineer UL LLC

2. Introduction

The equipment under test (EUT) contains Qualcomm FastConnect WLAN adapter supporting 2GHz, 5GHz, and 6GHz WLAN. In general, regulatory RF exposure limits are defined with respect to time-averaged RF exposure. Qualcomm FastConnect WIFI TAS algorithm performs transmit power control to ensures at all times the wireless device is in compliance with the configured limit of RF exposure averaged over a defined time window denoted as TSAR for SAR and PD

Note: For FCC. Wi-Fi 6E operates in the 6GHz ~ 7GHz band. The Interim RF Exposure Test Procedures for U-NII 6-7GHz Portable Devices also requires RF exposure assessment with SAR and incident PD (total) using mmW near-field probe and total-field/power-density reconstruction method. TAS validation performed in this report was done with SAR procedures consistent with Qualcomm's FastConnect documentation.

The FastConnect WIFI TAS supports maximum time-averaging windows (denoted as TSAR) as defined by the FCC that a 30 second time-averaging window is used by FastConnect WIFI TAS for WLAN operation in 2.4GHz, 5GHz, and 6GHz WLAN bands.

FastConnect WIFI TAS manages the instantaneous transmit power to maintain the time-averaged power and associated RF exposure is below the regulatory compliance limit.

- If the time-averaged transmit power approaches the SAR compliance power, then the instantaneous transmit power is limited to ensure the time-averaged transmit power does not exceed the SAR compliance power in any TSAR time window (i.e., the time-averaged RF exposure complies with the FCC or ICNIRP RF exposure limit in any time window).
- The wireless device can instantaneously transmit at high transmit powers for a short time durations before limiting the power to maintain time-averaged SAR compliance.

2.1. Supported WLAN operations

- IEEE 802.11‑Operation in 2GHz, 5GHz, and 6GHz U-NII frequencies.
- SISO‑Operation using a single antenna. The transmit chain may switch during operation. While using a single antenna, a design may support transmitting WLAN packets in 2GHz, 5GHz, or 6GHz channels.

  Note: SISO operation depends on implementation in software. SISO mode may not be supported when software enables cyclic delay diversity (CDD). In this case WLAN always transmits in MIMO mode.

- MIMO‑Operation using two antennas with one or more spatial streams.
- Dual band simultaneous (DBS) and/or High Band simultaneous (HBS)‑Packets are transmitted in separate frequencies at the same time. A device may operate in DBS using MIMO or SISO.

  Note: DBS operation support depends on implementation in software.

3. 2 FastConnect WIFI TAS parameters

This chapter defines the key parameters required for FastConnect WIFI TAS:

- $RFexp_{target}$
- P_{lim}
- P_{max}

3.1. RFexptarget

The $RFexp_{target}$ for FastConnect WIFI TAS WLAN is the device specific RF exposure limit (SAR or APD depends on operation band) used in the Fast Connect WIFI TAS algorithm for WLAN operation (antenna, band and DSI state) in a country. This $RFexp_{target}$ is pre-determined for each specific device, and it shall be less than regulatory RF exposure limit after accounting for all design related tolerances (device uncertainty) and the simultaneous transmission with other radios[Note] are taken into account in the $Rfexp_{target}$ values.

Determination of the $Rfexp_{target}$ is discussed in Section 4.1.

3.2. Plim

P_{lim} (in dBm) is the power corresponding to the $Rfexp_{target}$ for FastConnect WIFI TAS WLAN. In other words, P_{lim} is the maximum time-average transmit power setting for FastConnect WIFI TAS, at which this radio configuration (i.e., antenna, band and DSI state) reaches the $Rfexp_{target}$. The Fast Connect WIFI TAS algorithm uses P_{lim} to transmit power to ensure the real time-averaged SAR is below the $RFexp_{target}$ in real time and thus ensure device RF Exposure compliance. P_{lim} values vary with configuration (band, antenna and DSI), therefore it has the unique value for each configuration.

Hence, (P_{lim} + device uncertainty (in dB)) should be treated as *reported* power for the worst-case technologies of given radio configuration and used for assessment of all relevant RF exposure exclusion criteria.

In the FastConnect WIFI TAS operation, transmission power can exceed P_{lim} for periods of time if the time-averaged SAR limit is not violated. P_{lim} represents the maximum time average power over a specified time window for the corresponding radio configuration to be compliant with the $RFexp_{target}$. The P_{lim} values is stored in the FastConnect WIFI TAS board data file (BDF) and used by FastConnect WIFI TAS.

In the FastConnect WIFI TAS operation, the BDF provides the P_{lim} populated in different values and across a range of WLAN frequencies as follows:

- Separate P_{lim} values for different regulatory limit (FCC or ICNIRP limit)
- Separate P_{lim} values per band
- Separate P_{lim} values per mode for SISO vs. MIMO
- Multiple P_{lim} tables per DSI

3.3. Pmax

P_{max} for FastConnect WIFI TAS WLAN represents the maximum WLAN transmit power from other power setting in board data file. The P_{max} value could be identified by compare the target power (Rate-to-Power) and compliance transmit (CTL) and other power limit.

P_{max} = min {CTL, Regdomain, TPE/TPC, Rate-to-Power}

3.4. DUT support configuration

3.4.1. Plim values stored in the board data file (BDF)

FastConnect WIFI TAS supports separate Plim values for the following:

- Separate Plim value per FCC and ICNIRP limit
- Separate Plim value for SISO and MIMO
- Multiple Plim tables per DSI

The WLAN BDF is populated by the device manufacture with the Plim format listed in the following table. Data for each row are determined through SAR characterization and Static SAR testing.

***Plim* values**

Tx Chain	P_{lim} Setting
2GHz (Chain0)	19.25
2GHz (Chain1)	19.25
5GHz (Chain0)	12.00
5GHz (Chain1)	13.25
6GHz (Chain0)	9.50
6GHz (Chain1)	9.25

Notes:
1. *Plim* values are in 0.25 dB increments.
2. BDF optionally may be configured with different *Plim* values across a range of WLAN frequencies within each band.
3. The *Plim* values entered in BDF reflect device uncertainty.
4. Reserve margin = 1 dB

DUT radio TX chain and antenna map

Tx Chain	Antenna Group
2GHz (Chain0)	0
2GHz (Chain1)	1
5GHz (Chain0)	0
5GHz (Chain1)	1
6GHz (Chain0)	0
6GHz (Chain1)	1

4. FastConnect WIFI TAS Device SAR Characterization Procedure

SAR characterization must be generated to cover all radio configurations and usage sicarios for FastConnect WIFI TAS device. It will be used as input for FastConnect WIFI TAS to control and manage RF exposure.

4.1. Usage scenario in SAR evaluation

The device state index (DSI) represents each device usage scenario (or exposure scenario). Depending on the scheme implemented in the FastConnect WIFI TAS device, the worst-case RF exposure scenario is further grouped and determined for each or combined exposure scenario(s). Example below for notebook computer supporting <6GHz RF exposure scenario:

- If the device does not have any detection mechanism, then the worst-case 1gSAR is determined by taking the maximum 1gSAR value among all exposure scenarios.

  For example, A FastConnect WIFI TAS laptop supports laptop mode (*DSIlaptop*) and Tablet mode (*DSItablet*) without support any detection mechanism to manage different power level (*Plim*) for DSIs. And *SARlaptop, SARtablet* is correspond *RFexptarget* for *DSIlaptop* and *DSItablet.* Then the worst-case body 1gSAR is determined:

  worst-case 1gSAR = *max*{*SARlaptop, SARtablet*}

- If the device can distinguish each of the above scenarios, then the worst-case 1gSAR for each individual exposure scenario is given by corresponding exposure scenarios, i.e., SAR_{laptop} *and* SAR_{tablet}.

4.2. Device uncertainty

$RFexp_{target}$ should take device uncertainty (in dB) into consideration that:

$RFexp_{target} \times 10^{(+\text{device uncertainty}/10)} <$ Regulation RF exposure limit for WLAN managed by FastConnect WIFI TAS

4.3. SAR Characterization

The design target (denoted as *RFexptarget*) for RF exposure compliance (1g SAR or 10g SAR or PD) must be specified for FastConnect WIFI TAS WLAN before determining the power level required to meet the *RFexptarget* for each radio configuration and usage case supported. The SAR characterization procedure is as follows:

1. Specify *RFexptarget*: The *RFexptarget* shall be less than regulatory limit after accounting for all device uncertainties.
2. Measure the conducted power (denote as Measured_Power_*Ptest*) and SAR (denoted as Measured_SAR_*Ptest*) or PD (denoted as Measured_PD_*Ptest*) at low, middle, and high channels for each Tx antenna and supported band. For a given antenna that supports multiple technology modulations (for example, 802.11b/g/n/ac etc.) at same band, choose the representative modulation that has the maximum *Pmax* setting from the technologies supported in each band. Note that PD can be incident power density (iPD) or absorbed power density (APD) depending on the regulatory market. For Canada, the metric is defined as APD by ISED.
3. Based on the 1gSAR (or 10gSAR or PD) values obtained in step 2, Determine the *Plim* Tx power level at which the corresponding 1gSAR is equal to *RFexptarget* for each channel in the given antenna/band/DSI by:

$$P_{lim} = \text{Measured\_Power}\ P_{test} + 10 * \log\left(\frac{RFexptarget}{\text{Measured\_SAR\_}Ptest}\right) \quad \text{or}$$

$$P_{lim} = \text{Measured\_Power\_}P_{test} + 10 * \log\left(\frac{RFexptarget}{\text{Measured\_PD\_}Ptest}\right)$$

   If the DSI are distinguishable, then the resulted Tx power levels should be separated (e.g., *SARlaptop_Plim and SARtablet_Plim*) correspond to the wort-case1gSAR of each DSI respectively (e.g., *DSIlaptop* and *DSItablet*) at given antenna/band.

   Denote the respective calculated *Plim* for low, middle and high channel for an antenna/band as *SARlaptop_Plim_Low_CH , SARlaptop_ Plim_Mid_CH* and *SARlaptop_ Plim _High_CH* for *DSIlaptop* and *SARtablet_Plim_Low_CH , SARtablet_Plim_Mid_CH* and *SARtablet_Plim_High_CH* for *DSItablet*
4. For below 6GHz operation. The FCC has specified 1gSAR and 10gSAR for different RF exposure scenarios (e.g., antenna close to the notebook keyboard or mouse touchpad). In this case, *RFexptarget* is defined for 1gSAR first, and then calculate the Tx power level at which the corresponding worst-case 10gSAR is equal to the design target for 10gSAR compliance, *RFexptarget _extremity*, as follows:
   a. Derive *RFexptarget_extremity* for hand exposure scenario that has similar normalized exposure ratio relative to the regulatory limit using:

$$RFexp_{target\_extremity} = \frac{RFexptarget}{\text{1gSAR limit}} \times 10gSAR\ limit$$

   b. For a specific DSI that is required to support both 1gSAR and 10gSAR. Determine the *Plim* that corresponds to 1g SAR target (*RFexptarget_body*) and 10gSAR target (*RFexptarget_extremity*), denoted as *SARbody_Plim* and *SARextremity_Plim.* then*:* *Plim* = min (*SARbody_Plim* , *SARextremity_Plim*) for the specific DSI should be applied for each antenna/band.
5. Generate SAR characterization table for each Tx antennas.
6. The above procedures are also applicable for WLAN operation above 6GHz that RF exposure to be assessed use APD (absorbed PD) or IPD (incident PD).

4.4. SAR test procedure

This section provides test procedure for SAR characterization for operation below 6GHz bands. The SAR measurement should be performed at static Tx power transmission mode

Qualcomm Radio Control Toolkit (QRCT) test software could be used for WLAN radio conformance testing of in-band and out-of-band emissions as well as SAR testing. QRCT supports Tx99 continuous transmission modes that meets the transmission duty cycle requirement per FCC and ISED test procedures.

1. SAR should be tested at an initial power (denoted as *Ptest*). In general. The recommended *Ptest* is the highest *Pmax* mode from the amount of modulation support in the band as initial power for test.
    a. *Pmax* could be identified by compare the board target Power and compliance transmit limit (CTL) per technologies (modulation, bandwidth, channel) for each mode, band.

        NOTE: In Qualcomm WLAN software implementation, the target power and CTL setting is stored in the BDF for Wi-Fi 6E chips. The CTL engine takes both target power and CTL exemptions in transmission for Wi-Fi 7 chips.

    b. Before the SAR test, calibrate the test samples and confirm the measured conducted power is within 2dB lower than the maximum tune-up tolerance limit per Section 3.1.3 in KDB 447498 D04.
2. Determine test configuration and *Ptest*

    In FastConnect WIFI TAS. *Plim* represents the maximum, time-averaged power over a specified time window and applies same value to all support WLAN technologies (802.11 modulations) for each antenna, band and DSI. Hence the initial test configuration and *Ptest* should consider and cover:

    a. Worst case WLAN technologies support from each antenna/band.

    b. Highest *Pmax* channel and rate of that modulation in the given antenna/band.

        NOTE: Refer to FCC KDB 248227 D01 802.11 Wi-Fi SAR and KDB447498 D01 for details of SAR measurements and test reduction Configurations for Wi-Fi® devices.

3. SAR characterization as described in #2 and #3 in Section 4.3. *Plim* is determined in following procedure:
    i. Measure SAR use FTM mode at representative modulation in low, middle, and high channels at initial power *Ptest*.

    ii. Scale (up or down) the SAR value from step (i) to *RFexptarget* for each channel of the given antenna/band/DSI to calculate the exact value. The calculated *Plim* must be adjusted to a final *Plim* value that is a 0.25 dB increment to be equal or less than the calculated *Plim*.

    iii. The above procedure are also applicable for WLAN operation above 6GHz that RF exposure to be assessed use APD (absorbed PD) or IPD (incident PD). The PD measurement should be performed to determine *Plim*.

5. EUT Characterization Results

5.1. SAR characterization and SAR test

This section provides a reference of SAR characterization of EUT and P_{lim} to be determined for TAS Static SAR compliance test. The following table is a reference of SAR characterization and validation of P_{lim} as per Section 4.4.

SAR characterization and P_{lim}

Band	Antenna	Channel	Modulation	Measured Power (dBm)	Measured 1g SAR at Ptest (W/kg)	Calculated Plim (dBm)	Maximum Plim determination for TAS BDF (Power Setting in 0.25 step)	Configured Plim TAS BDF (Power Setting in 0.25 step)
2.4	C0	6	802.11b	19.16	0.441	22.72	22.50	19.25
	C1	6	1 Mbps	18.81	0.301	24.02	24.00	
5.2 & 5.3	C0	62	802.11ac VHT40 MCS0	13.82	0.561	16.33	16.25	13.75
	C1	60	802.11a 6Mbps	16.30	0.961	16.47	16.25	15.50
5.6	C0	122	802.11ac VHT80 MCS0	14.65	0.943	14.90	14.75	13.75
	C1	114	802.11ac VHT160 MCS0	13.96	0.960	14.14	14.00	13.25
5.8 & 5.9	C0	163	802.11ac VHT160 MCS0	12.52	0.968	12.66	12.50	12.00
	C1	163	802.11ac VHT160 MCS0	13.62	0.951	13.84	13.75	13.25
6	C0	31	802.11be EHT320 MCS0	10.18	0.416	13.99	13.75	9.50
		95		9.59	0.345	14.21	14.00	
		159		10.04	0.335	14.79	14.75	
		191		9.89	0.318	14.87	14.75	
	C1	31		9.37	0.293	14.70	14.50	9.25
		95		9.56	0.262	15.38	15.25	
		159		9.36	0.323	14.27	14.25	
		191		9.48	0.261	15.31	15.25	

5.2. APD characterization and APD test

This section provides a reference of APD characterization of EUT and P_{lim} to be determined for TAS Static SAR compliance test. Following table is a reference of APD characterization and validation of P_{lim} as per procedure introduced in Section 4.4

APD characterization and P_{lim}

Band	Antenna	Channel	Modulation	Measured Power (dBm)	Measured APD (W/m^2 over 4cm^2)	Calculated Plim (dBm)	Maximum Plim determination for TAS BDF (Power Setting in 0.25 step)	Configured Plim TAS BDF (Power Setting in 0.25 step)
6	C0	31	802.11be EHT320 MCS0	10.18	3.200	16.10	16.00	9.50
		95		9.59	2.700	16.25	16.00	
		159		10.04	2.590	16.88	16.75	
		191		9.89	2.510	16.86	16.75	
	C1	31		9.37	2.190	16.93	16.75	9.25
		95		9.56	1.870	17.81	17.75	
		159		9.36	2.370	16.58	16.50	
		191		9.48	1.900	17.66	17.50	

5.3. IPD characterization and IPD test

This section provides a reference of IPD characterization of EUT and P_{lim} to be determined for TAS Static SAR compliance test. Following table is a reference of IPD characterization and validation of P_{lim} as per procedure introduced in Section 4.4

IPD characterization and P_{lim}

Band	Antenna	Channel	Modulation	Measured Power (dBm)	Measured IPD (mW/cm^2 over 4cm^2)	Calculated Plim (dBm)	Maximum Plim determination for TAS BDF (Power Setting in 0.25 step)	Configured Plim TAS BDF (Power Setting in 0.25 step)
6	C0	31	802.11be EHT320 MCS0	10.18	0.611	11.07	11.00	9.50
		95		9.59	0.521	11.17	11.00	
		159		10.04	0.497	11.83	11.75	
		191		9.89	0.514	11.53	11.50	
	C1	31		9.37	0.420	11.89	11.75	9.25
		95		9.56	0.402	12.27	12.25	
		159		9.36	0.499	11.13	11.00	
		191		9.48	0.338	12.94	12.75	

End of Report