KDB 865664 D01 SAR Measurement 100MHz to 6GHz
FCC 47 CFR part 2 (2.1093)

SAR EVALUATION REPORT

For

Single Board Computer

Model Name*: Raspberry Pi 500
Contains FCC ID*: 2ABCB-RPI500

REPORT NUMBER UL-SAR-RP15519285JD02A V1.0
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Prepared for

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REVISION HISTORY

Ver.	Issue Date	Revisions	Revised By
1.0	10 December 2024	Initial Issue	--

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1. Attestation of Test Results

Applicant Name:	Raspberry Pi (Trading) Ltd					
Model*:	Raspberry Pi 500					
Applicable Standards:	FCC 47 CFR part 2 (2.1093) IEEE Std 1528:2013 KDB publications					
Test Device is	A representative test sample					
Device category*:	Portable					
Date Tested:	11 Nov 2024 to 27 Nov 2024					
FCC 47 CFR part 2 Guidelines Limits for SAR Exposure Characteristics	General Population/Localised SAR (Extremity) – 10g-SAR limit 4.0 W/kg					
The highest reported SAR values for Localized SAR	RF Exposure Conditions		Equipment Class			
			Licensed	DTS	U-NII	DSS
	Standalone	Extremity	N/A	0.30 W/Kg	2.61W/Kg	N/A
	Simultaneous Transmission	Extremity	N/A	N/A	N/A	N/A
Test Results:	Pass					

1. This test report shall not be reproduced except in full without the written approval of UL International (UK) Ltd.
2. The results documented in this report apply only to the sample(s) tested.
3. All Pass/Fail indications in this report are observations based on the measurements recorded herein from testing performed in accordance with the standards named above.
4. The measurements in this report are traceable to national or international standards.
5. This report must not be used by the client to claim product certification, approval, or endorsement by UKAS.
6. This report is written to support regulatory compliance of the standards named above.
7. Throughout this report, all information marked with (*) was provided by customer, Applicant or Authorised representative.

Issued By:	Prepared By:
	
Naseer Mirza Operations Leader	Masood Khan Senior Test Engineer

2.Test Specification, Methods and Procedures

2.1.Test Specification

Reference:	KDB Publication Number: 865664 D01 SAR Measurement 100 MHz to 6 GHz
Title:	SAR Measurement Requirements for 100 MHz to 6 GHz
Introduction:	The SAR Measurement procedures for 100MHz to 6GHz are described in this document. Field probes, tissue dielectric properties, SAR scans, measurement accuracy and variability of the measured results are discussed. The field probe and SAR scan requirements are derived from criteria considered in standard IEEE 1528-2013. The wireless product and technology specific procedures in applicable KDB publications are required to be used unless further guidance has been approved by the FCC.
Purpose of Test:	To determine if the Equipment Under Test complies with the Specific Absorption Rate for general population/uncontrolled exposure limit of 1.6 W/kg as specified in FCC 47 CFR part 2 (2.1093).

2.2. Methods and Procedures Reference Documentation

The methods and procedures used were as detailed in:

IEEE 62209-1528:2013

IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communication Devices: Measurement Techniques.

FCC KDB Publication:
KDB 248227 D01 802 11 Wi-Fi SAR v02r02
KDB 447498 D01 General RF Exposure Guidance v06
KDB 447498 D03 Supplement C Cross-Reference v01
KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz v01r04
KDB 865664 D02 RF Exposure Reporting v01r02

2.3. Definition of Measurement Equipment

The measurement equipment used complied with the requirements of the standards referenced in the methods & procedures section above. Section 4.3 contains a list of the test equipment used.

3.Facilities and Accreditation

The measurement facilities used to collect data are located at

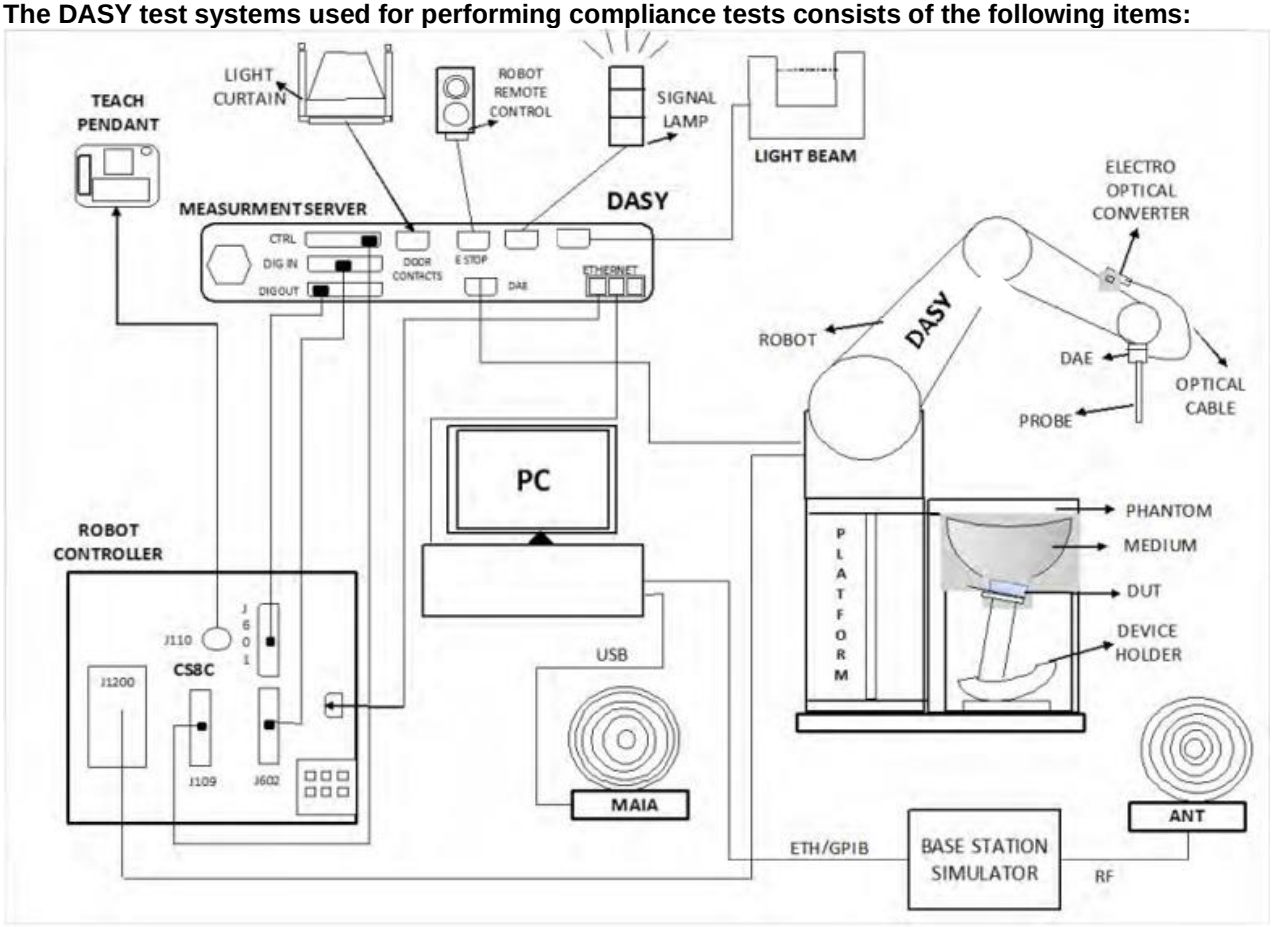
Horizon Unit 1-4, Wade Road, Kingsland Business Park, Basingstoke, Hampshire, RG24 8AH, UK	Facility Type
SAR Lab 60	Controlled Environment Chamber
SAR Lab 66	Controlled Environment Chamber

UL International (UK) Ltd is accredited by UKAS (United Kingdom Accreditation Service, Accredited to ISO/IEC 17025:2017), Laboratory UKAS Code 5772.

4. SAR Measurement System & Test Equipment

4.1. SAR Measurement System

The DASY test systems 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 Win10 with DASY software installed.
- 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 Measurement Procedure

4.2.1. Normal SAR Measurement Procedure

The following procedure shall be performed for each of the test conditions

a) Measure the local SAR at a test point within 8 mm of the phantom inner surface that is closest to the DUT.

b) Measure the two-dimensional SAR distribution within the phantom (area scan procedure). The boundary of the measurement area shall not be closer than 20 mm from the phantom side walls. The distance between the measurement points should enable the detection of the location of local maximum with an accuracy of better than half the linear dimension of the tissue cube after interpolation. A maximum grid spacing of 20 mm for frequencies below 3 GHz and (60/f [GHz]) mm for frequencies of 3 GHz and greater is recommended. The maximum distance between the geometrical centre of the probe detectors and the inner surface of the phantom shall be 5 mm for frequencies below 3 GHz and δ ln(2)/2 mm for frequencies of 3 GHz and greater, where δ is the plane wave skin depth and ln(x) is the natural logarithm. The maximum variation of the sensor-phantom surface distance shall be ± 1 mm for frequencies below 3 GHz and ± 0,5 mm for frequencies of 3 GHz and greater. At all measurement points the angle of the probe with respect to the line normal to the surface should be less than 5°. If this cannot be achieved for a measurement distance to the phantom inner surface shorter than the probe diameter, additional uncertainty evaluation is needed.

c) From the scanned SAR distribution, identify the position of the maximum SAR value, in addition identify the positions of any local maxima with SAR values within 2 dB of the maximum value that will not be within the zoom scan of other peaks; additional peaks shall be measured only when the primary peak is within 2 dB of the SAR compliance limit (e.g., 1 W/kg for 1,6 W /kg 1 g limit, or 1,26 W/kg for 2 W /kg, 10 g limit).

d) Measure the three-dimensional SAR distribution at the local maxima locations identified in step c) (zoom For frequencies at or below 3 GHz, the following procedure shall be applied: The horizontal grid step shall be 8 mm or less. The grid step in the vertical direction shall be 5 mm or less if uniform spacing is used. If variable spacing is used in the vertical direction, the maximum spacing between the two closest measured points to the phantom shell (M1 and M2) shall be 4 mm or less and the spacing between farther points shall increase by a factor of 1,5 or less. The minimum size of the zoom scan volume shall be 30 mm by 30 mm by 30 mm

For frequencies above 3 GHz, the minimum size of the zoom scan volume may be reduced to 22 mm by 22 mm by 22 mm. The horizontal grid step shall be (24/*f* [GHz]) mm or less. If uniform spacing in the vertical direction is used, the grid step in the vertical direction shall be (10/(*f* [GHz] − 1)) mm or less. If variable spacing is used in the vertical direction, the maximum spacing between the two measured points closest to the phantom shell shall be (12/*f* [GHz]) mm or less and the spacing between further points shall increase by a factor of 1,5 or less. For other parameters, see Zoom Scan Parameters table.

When the highest 1 g or 10 g cube is touching the boundary of a zoom-scan volume, the entire zoom scan shall be repeated with the new centre located at the maximum psSAR location indicated by the preceding zoom scan measurement. If the zoom scan measured as defined above complies with both of the following criteria, or if the peak spatial-average SAR is below 0,1 W/kg, no additional measurements are needed:

1) the smallest horizontal distance from the local SAR peaks to all points 3 dB below the SAR peak shall be larger than the horizontal grid steps in both *x* and y directions (Δ*x*, Δ*y*). This shall be checked for the measured zoom scan plane conformal to the phantom at the distance z_{M1}. The minimum distance shall be recorded in the SAR test report;

2) the ratio of the SAR at the second measured point (M2) to the SAR at the closest measured point (M1) at the *x-y* location of the measured maximum SAR value shall be at least 30 %. This ratio (in %) shall be recorded in the SAR test report.

If one or both of the above criteria are not met, the zoom scan measurement shall be repeated using a finer resolution while keeping the other zoom scan parameters compatible with Zoom Scan Parameters table. New horizontal and vertical grid steps shall be determined from the measured SAR distribution so that the above criteria are met. Compliance with the above two criteria shall be demonstrated for the new measured zoom scan. The size of the higher resolution zoom scan and other parameters of Zoom Scan Parameters table shall apply. The closest point to the phantom shell shall be 2 mm or less for graded grids and the grading factor shall be 1,5 or less.

Uncertainties due to field distortion between the media boundary and the dielectric enclosure of the probe should also be minimized, which is achieved if the distance between the phantom surface and physical tip of the probe is larger than the probe tip diameter. Other methods may utilize correction procedures to compensate for boundary effects that enable high precision measurements closer than half the probe diameter. For all measurement points, the angle of the probe normal to the flat phantom surface shall be less than 5º.

Zoom Scan Parameters

Parameter	DUT transmit frequency being tested	
	$f \leq 3$ GHz	3 GHz < $f \leq 6$ GHz
Maximum distance between the closest measured points and the phantom surface (z_{M1} in Figure 14 and Table 2, in mm)	5	$\delta \ln(2)/2$ [a]
Maximum angle between the probe axis and the flat phantom surface normal (α in Figure 14)	5°	5°
Maximum spacing between measured points in the x- and y-directions (Δx and Δy, in mm)	8	$24/f$ [b,c]
For uniform grids: Maximum spacing between measured points in the direction normal to the phantom shell (Δz_1 in Figure 14, in mm)	5	$10/(f - 1)$
For graded grids: Maximum spacing between the two closest measured points in the direction normal to the phantom shell (Δz_1 in Figure 14, in mm)	4	$12/f$
For graded grids: Maximum incremental increase in the spacing between measured points in the direction normal to the phantom shell ($R_z = \Delta z_2/\Delta z_1$ in Figure 14)	1,5	1,5
Minimum edge length of the zoom scan volume in the x- and y-directions (L_z in 7.2.5.3, in mm)	30	22
Minimum edge length of the zoom scan volume in the direction normal to the phantom shell (L_h in 7.2.5.3, in mm)	30	22
Tolerance in the probe angle	1°	1°

[a] δ is the penetration depth for a plane-wave incident normally on a planar half-space.

[b] This is the maximum spacing allowed, which may not work for all circumstances.

[c] f is the frequency in GHz.

e) Use post processing (e.g. interpolation and extrapolation) procedures to determine the local SAR values at the spatial resolution needed for mass averaging.

f) The local SAR should be measured at the same location as in Step a). SAR drift is assessed and reported in the uncertainty budget.

g) In the event that the evaluation of measurement drift exceeds the 5 % tolerance, it is required that SAR be reassessed following guidelines contained within this standard.

If the drift is larger than 5 %, then the measurement drift shall be considered a bias, not an uncertainty. A correction shall be applied to the measured SAR value. It is not necessary to record the drift in the uncertainty budget (i.e. ui = 0 %). The uncertainty budget reported in a measurement report should correspond to the highest SAR value reported (after correction, if applicable). Alternatively, the uncertainty budget reported should cover all measurements, i.e., it should report a conservative value.

4.3. Test Equipment

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

**Note: The test equipment was within 1-year annual calibration during the time of testing.

UL Asset No.	Instrument Name	Manufacturer	Type	Serial No.	Date Last Calibrated	Cal. Interval (Months)
168971	E-Field Probe	SPEAG	ES3DV3	3360	17 Sep 2024	12
234652	E-Field Probe	SPEAG	EX3DV4	7788	16 Jan 2024	12
168974	Data Acquisition Equipment	SPEAG	DAE4	1543	12 Feb 2024	12
235307	Data Acquisition Equipment	SPEAG	DAE4ip	1792	17 Apr 2024	12
171435	Phantom	SPEAG	ELI V8	2091	Cal. as part of system	-
206657	Phantom	SPEAG	ELI V8	2144	Cal. as part of system	-
130029	Dipole Antenna	SPEAG	D2450V2	725	07 Oct 2024	12
129547	Dipole Antenna	SPEAG	D5GHzV2	1016	09 Oct 2024	12
180463	POWERSOURCE1	SPEAG	SE UMS 160 BA	4012	07 Mar 2024	12
234639	POWERSOURCE1	SPEAG	SE UMS 160 CB	4315	09 Feb 2024	12
133921	RS Hygrometer	RS Components	408-6109	D10Q52	04 Mar 2024	12
133922	RS Hygrometer	RS Components	408-6109	D10Q69	04 Mar 2024	12
131777	Body Handset Positioner	SPEAG	MD4HACV5	None	Cal. not required	-
234946	Body Handset Positioner	SPEAG	MD4HACV5	None	Cal. not required	-
170221	Head Handset Positioner	SPEAG	MD4HHTV5	None	Cal. not required	-
234952	Head Handset Positioner	SPEAG	MD4HHTV5	None	Cal. not required	-
131898	Measurement Server	SPEAG	SE UMS 011 EA	1439	Cal. not required	-
234930	Measurement Server	SPEAG	-	10104	Cal. not required	-
138451	Phantom Support Structure	SPEAG	Phantom Table	-	Cal. not required	-
234955	Phantom Support Structure	SPEAG	Phantom Table	-	Cal. not required	-
131907	Robot Arm	Staubli	TX60 L	F14/5T5ZA1/A/01	Cal. not required	-
234926	Robot Arm	Staubli	TX2 60L	F/22/0042992/A/001	Cal. not required	-
131904	Robot Power Supply	SPEAG	CS8C	F14/5UA6A1/C/01	Cal. not required	-
234934	Robot Power Supply	SPEAG	CS9C	F/22/0042992/C/001	Cal. not required	-
166282	Power Sensor	Rohde & Schwarz	NRP-Z51	103031-NV	05 Dec 2023	12**
166281	Power Sensor	Rohde & Schwarz	NRP-Z51	104649-JG	28 Mar 2024	12
248445	Thermometer (Fluid)	R & S	Test 925	84796614	07 May 2024	12
248442	Thermometer (Fluid)	R & S	TEST0 925	84866571	07 May 2024	12
147741	Vector Network Analyser	Rohde & Schwarz	ZND 132.5170K92	100151	15 Feb 2024	12
235355	DAK 3.5 Fluid Probe	SPEAG	SM DAK 040 CA	1337	Cal. before use	-
133906	DAK 3.5 Fluid Probe	SPEAG	SM DAK 040 CA	1089	Cal. before use	-
212960	Digital Camera	Sony	DSC-HX400V	3245687	Cal. not required	-
184269	RF Coax Cable	Taoglas	CAB.721	-	Cal. not required	-
184271	RF Coax Cable	Taoglas	CAB.721	-	Cal. not required	-
134732	RF Coax Cable	-	70530/4PE	-	Cal. not required	-
137559	RF Coax Cable	Huber+Suhner	ST18/SMAm/Nm/36	-	Cal. not required	-

4.3.1. SAR System Specifications

Robot System		
Positioner:	Stäubli Unimation Corp. Robot Model: TX60L/ TX2-60L	
Repeatability:	±0.030 mm	
No. of Axes:	6	
Serial Number:	F/22/0042992/A/001, F14/5T5ZA1/A/01	
Reach:	920 mm	
Payload:	2.0 kg	
Control Unit:	CS8C, CS9C	
Programming Language:	V+	
Data Acquisition Electronic (DAE) System		
Serial Number:	DAE4 SN: 1543	DAE4ip SN: 1792
PC Controller		
PC:	Lenovo ThinkCentre M90t	
Operating System:	Windows 11	
Data Card:	DASY Measurement Server	
Data Converter		
Features:	Signal Amplifier, multiplexer, A/D converted and control logic.	
Software:	DASY6/ DASY8 PRO Software	
Connecting Lines:	Optical downlink for data and status info. Optical uplink for commands and clock.	
PC Interface Card		
Function:	24 bit (64 MHz) DSP for real time processing Link to DAE4 16 bit A/D converter for surface detection system serial link to robot direct emergency stop output for robot.	
Phantom		
Phantom:	ELI Phantom	
Shell Material:	Fibreglass	
Thickness:	2.0 ±0.2 mm (bottom plate)	
E-Field Probe		
Model:	EX3DV4	ES3DV3
Serial No:	7789	3360
Construction:	Triangular core	Triangular core
Frequency:	4 MHz to > 10 GHz	10 MHz to > 4 GHz
Linearity:	±0.2 dB (4 MHz to 10 GHz)	±0.2 dB (30 MHz to 4 GHz)
Probe Length (mm):	337	337
Probe Diameter (mm):	10	10
Tip Length (mm):	9	10
Tip Diameter (mm):	2.5	4
Sensor X Offset (mm):	1	2
Sensor Y Offset (mm):	1	2
Sensor Z Offset (mm):	1	2

5.Measurement Uncertainty

No measurement or test can ever be perfect and the imperfections give rise to error of measurement in the results. Consequently, the result of a measurement is only an approximation to the value of the measurand (the specific quantity subject to measurement) and is only complete when accompanied by a statement of the uncertainty of the approximation.

The expression of uncertainty of a measurement result allows realistic comparison of results with reference values and limits given in specifications and standards.

The uncertainty of the result may need to be taken into account when interpreting the measurement results.

The reported expanded uncertainties below are based on a standard uncertainty multiplied by an appropriate coverage factor, such that a confidence level of approximately 95% is maintained. For the purposes of this document “approximately” is interpreted as meaning “effectively” or “for most practical purposes”.

Test Name	Confidence Level	Calculated Uncertainty
Uncertainty- Freq. 300 MHz - 3 GHz Head & Body Configuration 10g	95%	±25.4%
Uncertainty- Freq. 3 GHz - 6 GHz Head & Body Configuration 10g	95%	±25.8%

The methods used to calculate the above uncertainties are in line with those recommended within the various measurement specifications. Where measurement specifications do not include guidelines for the evaluation of measurement uncertainty, the published guidance of the appropriate accreditation body is followed.

5.1.Method of Calculation

The methods used to calculate the above uncertainties are in line with those recommended within the various measurement specifications. Where measurement specifications do not include guidelines for the evaluation of measurement uncertainty, the published guidance of the appropriate accreditation body is followed.

5.2. Equipment Accuracy and Decision Rule

Measurement system instrumentation shall be used with an accuracy specification meeting the accuracy specification limits according to IEC/IECEE OD-5014.
As applicable, unless specified otherwise in this quotation, the compliance “Decision Rule” is based on Simple Acceptance. If the measured value is on the limit, the result is defined as a pass. In this case the risk of a false positive is 50%. For further information regarding risk assessment refer to ILAC G8:09/2019.

5.3.Uncertainty – Freq. 300MHz - 3 GHz Head & Body Configuration 10g

Type	Source of uncertainty	+ Value	- Value	Probability Distribution	Divisor	$c_{i\ (10g)}$	Standard Uncertainty		υ_i or υ_{eff}
							+ u (%)	- u (%)	
B	Probe calibration	12.000	12.000	normal (k=2)	2.0000	1.0000	6.000	6.000	∞
B	Probe calibration drift	1.700	1.700	Rectangular	1.7321	1.0000	0.981	0.981	∞
B	Probe Linearity and Detection Limits	4.700	4.700	Rectangular	1.7321	1.0000	2.714	2.714	∞
B	Broadband Signal	3.000	3.000	Rectangular	1.7321	1.0000	1.732	1.732	∞
B	Probe Isotropy	7.600	7.600	Rectangular	1.7321	1.0000	4.388	4.388	∞
B	Data Acquisition	0.300	0.300	normal (k=1)	1.0000	1.0000	0.300	0.300	∞
B	RF Ambient conditions	0.260	0.260	normal (k=1)	1.0000	1.0000	0.260	0.260	∞
B	Probe Positioning	0.700	0.700	normal (k=1)	1.0000	0.1400	0.098	0.098	∞
B	Data Processing Errors	4.000	4.000	Rectangular	1.7321	1.0000	2.309	2.309	∞
B	Uncertainty in SAR correction for deviations in permittivity and conductivity	1.900	1.900	normal (k=1)	1.0000	0.8400	1.596	1.596	∞
B	Liquid Conductivity (measured value)	5.288	5.288	normal (k=2)	1.0000	0.0000	0.000	0.000	∞
B	Liquid Permittivity (measured value)	2.500	2.500	normal (k=2)	1.0000	0.0000	0.000	0.000	∞
B	Liquid Conductivity (temperature uncertainty)	1.430	1.430	Rectangular	1.7321	0.7100	1.353	1.353	∞
B	Liquid Permittivity (temperature uncertainty)	0.310	0.310	Rectangular	1.7321	0.7100	0.127	0.127	∞
B	Phantom Shell Permittivity	14.000	14.000	Rectangular	1.7321	0.2500	2.021	2.021	∞
B	Distance DUT - TSL	2.000	2.000	normal (k=1)	1.0000	2.0000	4.000	4.000	∞
A	Test Sample Positioning	4.240	4.240	normal (k=1)	1.0000	1.0000	4.240	4.240	25
A	Device Holder uncertainty	6.090	6.090	normal (k=1)	1.0000	1.0000	6.090	6.090	5
B	DUT Modulation	2.400	2.400	Rectangular	1.7321	1.0000	1.386	1.386	∞
B	Drift of output power	5.000	5.000	Rectangular	1.7321	1.0000	2.887	2.887	∞
	Combined standard uncertainty			t-distribution			12.72	12.72	90
	Expanded uncertainty			k = 2			25.4	25.4	90

5.4.Uncertainty – Freq. 3 GHz - 6 GHz Head & Body Configuration 10g

Type	Source of uncertainty	+ Value	- Value	Probability Distribution	Divisor	$c_{i\ (10g)}$	Standard Uncertainty		υ_i or υ_{eff}
							+ u (%)	- u (%)	
B	Probe calibration	12.000	12.000	normal (k=2)	2.0000	1.0000	6.550	6.550	∞
B	Probe calibration drift	1.700	1.700	Rectangular	1.7321	1.0000	0.981	0.981	∞
B	Probe Linearity and Detection Limits	4.700	4.700	Rectangular	1.7321	1.0000	2.714	2.714	∞
B	Broadband Signal	3.000	3.000	Rectangular	1.7321	1.0000	1.501	1.501	∞
B	Probe Isotropy	7.600	7.600	Rectangular	1.7321	1.0000	4.388	4.388	∞
B	Data Acquisition	0.300	0.300	normal (k=1)	1.0000	1.0000	0.300	0.300	∞
B	RF Ambient conditions	0.260	0.260	normal (k=1)	1.0000	1.0000	0.260	0.260	∞
B	Probe Positioning	0.700	0.700	normal (k=1)	1.0000	0.2900	0.145	0.145	∞
B	Data Processing Errors	4.000	4.000	Rectangular	1.7321	1.0000	2.309	2.309	∞
B	Uncertainty in SAR correction for deviations in permittivity and conductivity	1.900	1.900	normal (k=1)	1.0000	0.8400	1.596	1.596	∞
B	Liquid Conductivity (measured value)	5.288	5.288	normal (k=2)	1.0000	0.0000	0.000	0.000	∞
B	Liquid Permittivity (measured value)	2.500	2.500	normal (k=2)	1.0000	0.0000	0.000	0.000	∞
B	Liquid Conductivity (temperature uncertainty)	1.430	1.430	Rectangular	1.7321	0.7100	1.394	1.394	∞
B	Liquid Permittivity (temperature uncertainty)	0.310	0.310	Rectangular	1.7321	0.7100	0.127	0.127	∞
B	Phantom Shell Permittivity	14.000	14.000	Rectangular	1.7321	0.2500	2.021	2.021	∞
B	Distance DUT - TSL	2.000	2.000	normal (k=1)	1.0000	2.0000	4.000	4.000	∞
A	Test Sample Positioning	4.240	4.240	normal (k=1)	1.0000	1.0000	4.240	4.240	25
A	Device Holder uncertainty	6.090	6.090	normal (k=1)	1.0000	1.0000	6.090	6.090	5
B	Drift of output power	5.000	5.000	Rectangular	1.7321	1.0000	2.887	2.887	∞
	Combined standard uncertainty			t-distribution			12.89	12.89	90
	Expanded uncertainty			k = 2			25.8	25.8	90

6. Equipment Under Test (EUT)

6.1. Description of Equipment Under Test (EUT)

DUT Description*:	The device under test is a 'single board computer'. DUT is a complete personal computer built into a compact keyboard and supports Wi-Fi 2.4GHz, Wi-Fi 5.0 GHz and Bluetooth 2.4 GHz bands.	
Serial Number*:	Radiated / Conducted Samples	Sample #1: 0774 Sample #2: 0775 Sample #3: 0776 Sample #4: 0777
Hardware Version Number*:	Raspberry Pi 500	
Software Version Number*:	Raspberry Pi OS	
Baseband Firmware Version*:	Raspberry Pi OS	
WLAN Firmware Version*:	Raspberry Pi OS	
Country of Manufacture*:	UK	
Date of Receipt:	11 November 2024	
Operating Configurations*:	Extremity (Hands/Limbs)	
Device dimension*:	Overall (Length x Width x Depth): 280 mm x 112 mm x 20mm	
Antenna Type*:	Integral – Niche Antenna	
Antenna Length*:	7mm	
Number of Antenna Positions*:	Antenna 1 – WLAN – Transmit/Receive	1 Fixed
Battery Type*:	☒ Power Via USB Type C ☐ Standard – Lithium-ion battery ☐ Extended (large capacity)	

6.2.Wireless Technologies

Wireless technologies	Frequency bands	Operating mode	Duty Cycle
Wi-Fi	2.4 GHz	802.11b 802.11g 802.11n (HT20) 802.11n (HT40)	100%
Wi-Fi	5 GHz	802.11a 802.11n (HT20) / 802.11ac (VHT20) 802.11n (HT40) / 802.11ac (VHT40) 802.11ac (VHT80)	100%
BT	2.4 GHz	BDR/EDR BLE	100%

Notes:

Additional Information Related to Testing:

Antenna Type:	Integral – Niche Antenna
Antenna Lengths:	7mm

Number of Antennas:	Antenna Type	Antenna Description	Type
	WLAN/Bluetooth	Wi-Fi 2.4GHz / 5GHz	1 fixed (Integral)

Wireless Technologies

Wi-Fi 2.4 & 5 GHz								
Band	Description							
	Channel No. 20 MHz BW	Freq. (MHz)	Channel No. 40 MHz BW	Freq. (MHz)	Channel No. 80 MHz BW	Freq. (MHz)	Channel No. 160 MHz BW	Freq. (MHz)
Wi-Fi 2.4 GHz (802.11b/g/n)	1	2412.0	N/A					
	2	2417.0						
	3	2422.0						
	4	2427.0						
	5	2432.0						
	6	2437.0						
	7	2442.0						
	8	2447.0						
	9	2452.0						
	10	2457.0						
	11	2462.0						
	12	2467.0						
	13	2472.0						
Wi-Fi 5.0 GHz 5.2 (U-NII-1) (802.11a/n/ac)	36	5180.0	38	5190.0	42	5210.0	50	5250.0
	40	5200.0						
	44	5220.0	46	5230.0				
	48	5240.0						
Wi-Fi 5.0 GHz 5.3 (U-NII-2A) (802.11a/n/ac)	52	5260.0	54	5270.0	58	5290.0		
	56	5280.0						
	60	5300.0	62	5310.0				
	64	5320.0						
Wi-Fi 5.0 GHz 5.6 (U-NII-2C) (802.11a/n/ac)	100	5500.0	102	5510.0	106	5530.0	114	5570.0
	104	5520.0						
	108	5540.0	110	5550.0				
	112	5560.0						
	116	5580.0	118	5590.0	122	5610.0		
	120	5600.0						
	124	5620.0	126	5630.0				
	128	5640.0						
	132	5660.0	134	5670.0	138	5690.0	-	-
	136	5680.0						
	140	5700.0	142	5710.0				
	144	5720.0						
Wi-Fi 5.0 GHz 5.8 (U-NII-3) (802.11a/n/ac)	149	5745.0	151	5755.0	155	5775.0		
	153	5765.0						
	157	5785.0	159	5795.0				
	161	5805.0						
	165	5825.0	-					

Bluetooth				
Band	Description			
	Frequency Range: 2402 - 2480 MHz			
	Mode	Channel Number	Channel Description	Frequency (MHz)
Bluetooth	BR Mode	0	Low	2402.0
		39	Middle	2441.0
		78	High	2480.0
	LE Mode	1	Low	2404.0
		19	Middle	2440.0
		39	High	2480.0

6.3.Nominal and Maximum Output power: Wi-Fi*

6.3.1.Wi-Fi 2.4 GHz

RF Air interface	Mode	Channel Nos.	Target + Max. Tolerances (dBm)
			SISO
Wi-Fi 2.4 GHz	802.11b	1	12.70
		6	12.70
		10	12.70
		11	12.80
	802.11g	1	15.30
		6	15.40
		10	15.40
		11	10.70
	802.11n HT20	1	15.40
		6	15.30
		10	9.40
		11	9.40
	802.11n HT40	3	13.40
		7	13.40
		11	13.60

Note: The powers above have been declared as module max. rated output powers including upper tolerance.

6.3.2.Wi-Fi 5 GHz

RF Air interface	Mode	Channel Nos.	Channel BW	Target + Max. Tolerances (dBm)
				SISO
Wi-Fi 5.2 GHz U-NII-1	802.11a	36	20 MHz	14.80
		40		16.90
		44		16.90
		48		16.40
	802.11n HT20	36		12.40
		40		12.70
		44		12.70
		48		12.70
	802.11n HT40	38	40 MHz	12.70
		46		15.60
	802.11ac VHT80	42	80 MHz	13.90
Wi-Fi 5.3 GHz U-NII-2A	802.11a	52	20 MHz	16.70
		56		16.70
		60		16.70
		64		16.40
	802.11n HT20	52		14.70
		56		15.60
		60		15.20
		64		15.20
	802.11n HT40	54	40 MHz	17.20
		62		15.40
	802.11ac VHT80	58	80 MHz	13.80
Wi-Fi 5.6 GHz U-NII-2C	802.11a	100	20 MHz	15.40
		104		16.40
		116		16.40
		140		16.80
	802.11n HT20	100		13.60
		104		15.50
		116		15.50
		136		15.50
		140		14.40
	802.11n HT40	102	40 MHz	14.10
		110		18.00
		118		18.10
		134		18.10
	802.11ac VHT80	106	80 MHz	13.00
		122		16.50
Wi-Fi 5.8 GHz U-NII-3	802.11a	149	20 MHz	16.20
		153		16.20
		157		16.80
		161		16.80
		165		16.80
	802.11n HT20	149		16.10
		153		15.50
		157		15.50
		161		15.00
		165		15.00
	802.11n HT40	151	40 MHz	17.50
		159		17.60
	802.11ac VHT80	155	80 MHz	17.60

Note: The powers above have been declared as module max. rated output powers including upper tolerance.

6.3.3.Bluetooth 2.4 GHz

RF Air interface	Mode	Channel Nos.	Target + Max. Tolerances (dBm)
			SISO
BT 2.4GHz	BDR	All	6.5
	BLE	All	4.7

Note: The powers above have been declared as module max. rated output powers including upper tolerance.

7. RF Exposure Conditions (Test Configurations)

7.1. Configuration Consideration

Technology Port	Configuration	DUT-to-User Separation	Position	Antenna-to-Edge Separation (mm)	Evaluation Considered
Wi-Fi 2.4/ 5GHz	Extremity (Hand / Limbs)	0mm	Front	< 25	Yes
			Back	< 25	Yes
			Back Tilt	< 25	Yes[2]
			Top	< 25	No[3]
			Edge Right	< 25	Yes
			Edge Left	> 25	No
			Edge Bottom	> 25	No

Notes:

1. The Antenna to edge separation distances is indicated in the 'Antenna Schematics' located in Section 11.1 of this report
2. It was found that a small separation distance between the phantom and DUT (at the location of the antenna) was made by positioning the four feet flat to the phantom in the standard "Back" position. Thus "Back Tilt" was evaluated by positioning the device with the keys parallel to the phantom surface, giving a slight tilted angle, thus reducing the separation distance.
3. The Top edge is not considered for evaluation as this condition is not a valid use-case for the DUT. The device requires certain cables to be plugged into it for it to function, which are located on the top edge, thus obstructing the user from exposure.

7.2. SAR Test Exclusion Consideration

Frequency Band	Configuration(s)
	Extremity
Wi-Fi 2.4 GHz	No
WLAN 5.2 GHz (U-NII-1)	Yes[3]
WLAN 5.3 GHz (U-NII-2A)	No
WLAN 5.6 GHz (U-NII-2C)	No
WLAN 5.8 GHz (U-NII-3)	No
Bluetooth 2.4GHz	Yes[1]

Note:

1. As per KDB publication 447498 D01, the frequency bands with rated power including upper tolerance, which qualify for Standalone Test Exclusion, are as per the above table.
2. The details for the Maximum Rated Power and tolerance(s) can be found in section 6.
3. As per KDB 248227, U-NII-2 was chosen for SAR evaluation as maximum rated power for U-NII-1 < U-NII-2A. Based on the measurements obtained, SAR measurements on U-NII-1 band are not required as highest reported SAR from U-NII-2A band is ≤ **1.20** W/Kg.

8.Conducted output power measurements

8.1.RF Output Average Power Measurement: Wi-Fi 2.4 GHz

		Avg Power (dBm)	
		Ant 1	
Channel Number	Frequency (MHz)	6.0 Mbps	Operating Mode
		Limbs	
1	2412	15.16	802.11g
6	2437	14.86	
10	2457	14.96	
11	2462	10.56	

Note:

1. Conducted power measurements on 802.11b, 802.11n HT20 and 802.11n HT40 modes were not performed as max. rated power including tolerance is equal or lower than other modes.

8.2. RF Output Average Power Measurement: Wi-Fi 5.0 GHz

8.2.1. Wi-Fi 802.11a (5.0 GHz) – 5.2 GHz U-NII-1

		Avg Power (dBm)	
		Ant 1	
Channel Number	Frequency (MHz)	6.0 Mbps	Operating Mode
		Limbs	
36	5180	14.70	802.11a
40	5200	16.50	
44	5220	16.40	
48	5240	16.10	

Note:

1. Conducted power measurements on 802.11n HT20, 802.11n HT40 and 802.11ac VHT80 modes were not performed as max. rated power including tolerance is equal or lower than other modes.

8.2.2. Wi-Fi 802.11a/n (5.0 GHz) – 5.3 GHz U-NII-2A

		Avg Power (dBm)	
		Ant 1	
Channel Number	Frequency (MHz)	6.0 Mbps	Operating Mode
		Limbs	
52	5260	16.50	802.11a
56	5280	16.40	
60	5300	16.40	
64	5320	16.10	

		Avg Power (dBm)	
		Ant 1	
Channel Number	Frequency (MHz)	13.5 Mbps	Operating Mode
		Body	
54	5270	17.00	802.11n HT40
62	5310	15.10	

Note:

1. Conducted power measurements on 802.11n HT20 and 802.11ac VHT80 modes were not performed as max. rated power including tolerance is equal or lower than other modes.

8.2.3. Wi-Fi 802.11a/n (5.0 GHz) – 5.6 GHz U-NII-2C

		Avg Power (dBm)	
		Ant 1	
Channel Number	Frequency (MHz)	6.0 Mbps	Operating Mode
		Body	
100	5500	15.10	802.11a
104	5520	15.90	
116	5580	16.20	
140	5700	16.50	

		Avg Power (dBm)	
		Ant 1	
Channel Number	Frequency (MHz)	13.5 Mbps	Operating Mode
		Body	
102	5510	13.90	802.11n HT40
110	5550	17.60	
118	5590	17.30	
134	5670	17.20	

Note:

1. Conducted power measurements on 802.11n HT20 and 802.11ac VHT80 modes were not performed as max. rated power including tolerance is equal or lower than other modes.

8.2.4. Wi-Fi 802.11ac (5.0 GHz) – 5.8 GHz U-NII- 3

		Avg Power (dBm)	
		Ant 1	
Channel Number	Frequency (MHz)	29.3 Mbps	Operating Mode
		Body	
155	5775	17.30	802.11ac VHT80

Note:

1. Conducted power measurements on 802.11n HT20, 802.11n HT40 and 802.11a modes were not performed as max. rated power including tolerance is equal or lower than other modes.

8.3. RF Output Average Power Measurement: Bluetooth 2.4 GHz

Note:

1. Conducted power measurements for BDR and BLE modes were not performed as max. rated power including tolerance qualify for SAR test exemption.

9. Measurements, Examinations and Derived Result

9.1. Specific Absorption Rate – Test Results – Wi-Fi 2.4 GHz

Test Approach

The SAR test is evaluated on each mode / configuration (Configuration: Face Mounted, Body-worn and Limbs) on the channel measuring the highest average output power, in each frequency band (i.e.: DTS)

In the cases where the different channel bandwidth modes have the same highest measured average power, the largest channel bandwidth configuration has been selected.

Note

1. Refer to section 7 for the configuration considered for SAR test.

9.1.1. WLAN 2.4GHz Extremity 10g 0mm Ant 1
Max Reported SAR = 0.30 (W/kg)

					Power (dBm)		10g: SAR Results (W/kg)				
Mode	Dist. (mm)	EUT Position	Channel Number	Freq (MHz)	Tune Up Limit	Meas.	Meas. SAR Level	Reported SAR	Transmitting Antenna	Notes	Plot No.
802.11g	0	Back Tilt	1	2412.0	15.30	15.16	0.247	0.26	Ant 1	-	-
802.11g	0	Back	1	2412.0	15.30	15.16	0.244	0.25	Ant 1	-	-
802.11g	0	Front	1	2412.0	15.30	15.16	0.046	0.05	Ant 1	-	-
802.11g	0	Edge Right	1	2412.0	15.30	15.16	0.032	0.03	Ant 1	-	-
802.11g	0	Back Tilt	6	2437.0	15.40	14.86	0.266	0.30	Ant 1	-	001
802.11g	0	Back Tilt	10	2457.0	15.40	14.96	0.261	0.29	Ant 1	-	-

Note(s):

9.2. Specific Absorption Rate - Test Results – Wi-Fi 5.0 GHz

Test Approach

The SAR test is evaluated on each mode / configuration (i.e.: Mode: Configuration: Face Mounted, Limbs 10g or Body) on the channel measuring the highest average output power, in each frequency band (i.e.: DTS, U-NII1, U-NII2A, U-NII2C, U-NII3).

In the cases where the different channel bandwidth modes have the same highest measured average power, the largest channel bandwidth configuration has been selected.

Note

1. Refer to section 7 for the configuration considered for SAR test.
2. As per KDB 248227, U-NII-2 was chosen for SAR evaluation as maximum rated power for U-NII-1 < U-NII-2A. Based on the measurements obtained, SAR measurements on U-NII-1 band are not required as highest reported SAR from U-NII-2A band is ≤ 3.00 W/Kg.

9.2.1. WLAN 5.3GHz Extremity 10g 0mm Ant 1
Max Reported SAR = 0.67 (W/kg)

					Power (dBm)		10g: SAR Results (W/kg)				
Mode	Dist. (mm)	EUT Position	Channel Number	Freq (MHz)	Tune Up Limit	Meas.	Meas. SAR Level	Reported SAR	Transmitting Antenna	Notes	Plot No.
802.11n HT40	0	Back Tilt	54	5270	17.20	17.00	0.482	0.50	Ant 1	-	-
802.11n HT40	0	Back	54	5270	17.20	17.00	0.460	0.48	Ant 1	-	-
802.11n HT40	0	Front	54	5270	17.20	17.00	0.154	0.16	Ant 1	-	-
802.11n HT40	0	Edge Right	54	5270	17.20	17.00	0.057	0.06	Ant 1	-	-
802.11n HT40	0	Back Tilt	62	5310	15.40	15.10	0.286	0.31	Ant 1	-	-
802.11a	0	Back Tilt	60	5300	16.70	16.40	0.602	0.65	Ant 1	-	-
802.11a	0	Back Tilt	64	5320	16.40	16.10	0.585	0.63	Ant 1	-	-
802.11a	0	Back Tilt	52	5260	16.70	16.50	0.637	0.67	Ant 1	-	002

Note(s):

9.2.2. WLAN 5.6GHz Extremity 10g 0mm Ant 1
Max Reported SAR = 1.56 (W/kg)

					Power (dBm)		10g: SAR Results (W/kg)				
Mode	Dist. (mm)	EUT Position	Channel Number	Freq (MHz)	Tune Up Limit	Meas.	Meas. SAR Level	Reported SAR	Transmitting Antenna	Notes	Plot No.
802.11n HT40	0	Back Tilt	102	5510	14.10	13.90	0.378	0.40	Ant 1	-	-
802.11n HT40	0	Back Tilt	110	5550	18.00	17.60	0.880	0.96	Ant 1	-	-
802.11n HT40	0	Back Tilt	118	5590	18.10	17.30	1.000	1.20	Ant 1	-	-
802.11n HT40	0	Back Tilt	134	5670	18.10	17.20	1.270	1.56	Ant 1	-	003
802.11a	0	Back Tilt	100	5500	15.40	15.10	0.700	0.75	Ant 1	-	-
802.11a	0	Back Tilt	104	5520	16.40	15.90	0.948	1.06	Ant 1	-	-
802.11a	0	Back Tilt	140	5700	16.80	16.50	1.130	1.21	Ant 1	-	-

Note(s):

9.2.3. WLAN 5.8GHz Extremity 10g 0mm Ant 1
Max Reported SAR = 2.61 (W/kg)

					Power (dBm)		10g: SAR Results (W/kg)				
Mode	Dist. (mm)	EUT Position	Channel Number	Freq (MHz)	Tune Up Limit	Meas.	Meas. SAR Level	Reported SAR	Transmitting Antenna	Notes	Plot No.
802.11ac VHT80	0	Back Tilt	155	5775	17.60	17.30	2.440	2.61	Ant 1	-	004

Note(s):

9.3. Specific Absorption Rate - Test Results – Bluetooth 2.4GHz

Note:

1. SAR Test is exempted as Max rated power including tolerance is below threshold.

9.4. SAR Measurement Variability

In accordance with published RF Exposure KDB procedure 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.

Body 10g-SAR:

1) Repeated measurement is not required when the original highest measured SAR is < 2.0 W/Kg; steps 2) through 4) do not apply.
2) When the original highest measured 10g-SAR is ≥ 2.00 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 ≥ 3.625 W/kg (~ 10% from the 10g-SAR limit).
4) Perform a third repeated measurement only if the original, first or second repeated measurement is ≥ 3.75 W/Kg and the ratio of largest to smallest SAR for the original, first and second repeated measurements is > 1.20.

Repeat Measurements Results

Exposure Configuration	Technology Band	EUT Position	Measured 10g - SAR (W/Kg)	Equipment Class	Max Meas. Source base Avg Power [dBm]	Ratio of Largest to Smallest SAR Measured
EXTREMITY (Separation Distance 0mm)	WLAN 5.8 GHz	Top	2.44	UNII	17.30	1.01
			2.41			

10.Highest Standalone SAR and Simultaneous Transmission

10.1.Highest Standalone Reported SAR

Individual Transmitter Evaluation per Band:

Exposure Configuration	Technology Band	Reported 10g - SAR (W/Kg)	Equipment Class	Highest Reported 10g - SAR (W/Kg)
Extremity (Hand / Limbs) (Separation Distance 0mm)	Wi-Fi 2.4 GHz	0.30	DTS	0.30
Extremity (Hand / Limbs) (Separation Distance 0mm)	WLAN 5.2 GHz	N/A	U-NII	2.61
	WLAN 5.3 GHz	0.67		
	WLAN 5.6 GHz	1.56		
	WLAN 5.8 GHz	2.61		

10.2.Simultaneous Transmission analysis

Simultaneous transmission SAR test exclusion is determined for each operating configuration and exposure condition according to the *reported* standalone SAR of each applicable simultaneous transmitting antenna. The worst-case simultaneous transmission analysis is considered for the following cases:

Note*: No simultaneous transmission analysis is required, as DUT does not support this feature.