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SAR EVALUATION REPORT

FCC 47 CFR Part 2.1093
ISED RSS-102

RF-Exposure evaluation of portable equipment

Report Reference No	G0M-1908-8377-TFC093SRGSM-V01
Testing Laboratory	Eurofins Product Service GmbH
Address	Storkower Str. 38c 15526 Reichenwalde Germany
Accreditation	ilac-MRA DAkkS Deutsche Akkreditierungsstelle D-PL-12092-01-03 ilac-MRA DAkkS Deutsche Akkreditierungsstelle D-PL-12092-01-04 DAkkS - Registration number : D-PL-12092-01-03 (ISED) DAkkS - Registration number : D-PL-12092-01-04 (FCC)
Applicant	BIOTRONIK SE & Co. KG
Address	Woermannkehre 1 12359 Berlin GERMANY
Test Specification Standard(s)	FCC 47 CFR 2.1093 ISED RSS-102 Issue 5 IEEE 1528:2013
Non-Standard Test Method	None
Equipment under Test (EUT):	
Product Description	CardioMessenger Smart / Telemonitoring System
Model(s)	CardioMessenger Smart 4G
Additional Model(s)	None
Brand Name(s)	BIOTRONIK
Hardware Version(s)	CardioMessenger Smart 4G mit LP best. LP1/Telex Smart 4G Rev Cx
Software Version(s)	ULP_HIGH_1_32_0, ULP_LOW_1_13_0, M0B.800004
FCC ID	QRI-CMSMART4GWW
IC	4708A-CMSMART4GWW
Contains FCC ID	N/A
Contains IC	N/A
Test Result	**PASSED**

Possible test case verdicts:	
Required by standard but not tested	N/T
Not required by standard	N/R
Not applicable to EUT	N/A
Test object does meet the requirement	P(PASS)
Test object does not meet the requirement	F(FAIL)
Testing:	
Test Lab Temperature	15 - 35 °C
Test Lab Humidity	30 – 50 %
Date of receipt of test item	2021-03-04

Report:		
Compiled by	Charline Graf	
Tested by (+ signature) (Responsible for Test)	Charline Graf	....
Approved by (+ signature) (Deputy Head of Lab)	Toralf Jahn	....
Date of Issue	2021-05-31	
Total number of pages	127	

General Remarks:

The test results presented in this report relate only to the object tested.

The results contained in this report reflect the results for this particular model and serial number. It is the responsibility of the manufacturer to ensure that all production models meet the intent of the requirements detailed within this report.

Additional Comments:

SAR EVALUATION SUMMARY

SAR Summary								
Exposure Condition		Equipment Classes						
		PCE	PCF	PCT	NII	DTS	DSS	TNT
Standalone-Tx	Head (1-g) [W/kg]	-	-	-	-	-	-	-
	Body-worn (1-g) [W/kg]	-	-	1.41100	-	-	-	-
	Hotspot (1-g) [W/kg]	-	-	-	-	-	-	-
	Extremities (10-g) [W/kg]	-	-	-	-	-	-	-
Simultaneous-Tx	Head (1-g) [W/kg]	-	-	-	-	-	-	-
	Body-worn (1-g) [W/kg]	-	-	1.41128	-	-	-	-
	Hotspot (1-g) [W/kg]	-	-	-	-	-	-	-
	Extremities (10-g) [W/kg]	-	-	-	-	-	-	-

VERSION HISTORY

Version History			
Version	Issue Date	Remarks	Revised By
01	2021-05-31	Initial Release	

ABBREVIATIONS AND ACRONYMS

Acronyms	
Acronym	Description
EIRP	Equivalent Isotropic Radiated Power
ERP	Effective Radiated Power
EUT	Equipment Under Test
LPE	Low Power Exclusion
SAR	Specific Absorption Rate

1 Equipment (Test Item) Under Test

General Information	
Description	**CardioMessenger** Smart / Telemonitoring System
Model	**CardioMessenger** Smart 4G
Additional Model(s)	**None**
Brand Name(s)	**BIOTRONIK**
Serial Number(s)	91630227
Hardware Version(s)	**CardioMessenger** Smart 4G mit LP best. LP1/Telex Smart 4G Rev Cx
Software Version(s)	**ULP**_HIGH_1_32_0, ULP_LOW_1_13_0, M0B.800004
FCC Certification	
FCC ID	QRI-CMSMART4GWW
ISED Certification	
IC	4708A-CMSMART4GWW
PMN	CardioMessenger Smart 4G
HVIN	CardioMessenger Smart 4G
FVIN	n/a
HMN	n/a
Equipment Classification	
Environment	General public
Type	Production Unit
Special Device Type	☐Handset ☒UMPC Mini-Tablet ☐USB Dongle ☐Non-specific
Number of radio chipsets/modules	2
Radio technologies of chipset/module 1	GSM
Radio technologies of chipset/module 2	MedRadio

Equipment Radio Chipset/Module 1		
GSM	Equipment Class	PCT
	Device class	C
	Dual Transfer Mode	No
	Frequency Band(s)	GSM 850 PCS 1900
	Frequency Range(s)	UL: 880-915 MHz UL: 1850-1910 MHz
	Power Class(es)	GSM 850: 4 GSM 1900: 2
	Mode(s)	GPRS EGPRS
	Modulation(s)	GMSK 8-PSK
	Multislot Class(es)	GPRS: 8 (D:4/U:1/S:5) EGPRS: 8 (D:4/U:1/S:5)
	Antenna	integrated GSM antenna
	Use case(s)	Body-worn
	Hotspot mode(s)	None

Equipment Radio Chipset/Module 2		
MedRadio	Equipment Class	TNT
	Frequency Range	402.45-404.85 MHz
	Mode(s)	2-FSK / 8 kbps 2-FSK / 197 kbps
	Antenna	MICS
	Use case(s)	Body-worn
	Hotspot mode(s)	None

2 Reference Documents

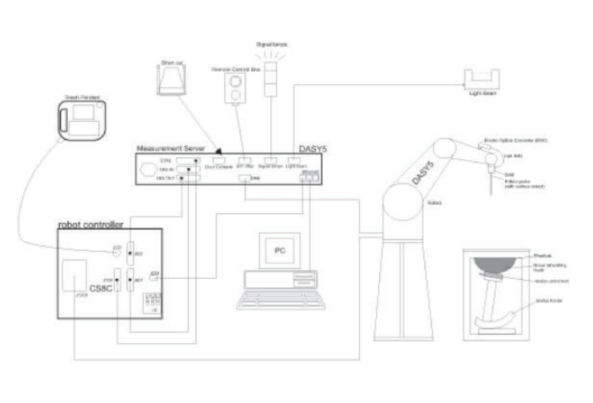
KDB Publications		
Name	**Description**	**Date**
447498 D01 v06	Mobile and Portable Devices RF Exposure Procedures And Equipment Authorization Policies	2015-10
865664 D01 v01r04	SAR Measurement Requirements for 100 MHz to 6 GHz	2015-08
865664 D02 v01r02	RF Exposure Compliance Reporting and Documentation Considerations	2015-10
648474 D03 v01r04	Evaluation and Approval Considerations for Handsets with Specific Wireless Charging Battery Covers	2015-12
941225 D03 v01	Recommended SAR Test Reduction Procedures for GSM-GPRS-EDGE	2008-12
680106 D01 v03	RF Exposure Considerations for Wireless Charging Applications	2018-04
616217 D04 v01r02	SAR Evaluation Consideration for Laptops and Netbooks and Tablets	2015-10
941225 D05 v02r05	SAR Evaluation Considerations for LTE Devices	2015-12
941225 D05A v01r02	Rel. 10 LTE SAR Test Guidance and KDB Inquiries	2015-10
648474 D04 v01r03	SAR Evaluation Considerations for Wireless Handsets	2015-10
941225 D06 v02r01	SAR Evaluation Procedures for Portable Devices with Wireless Router Capabilities	2015-10
941225 D07 v01r02	SAR Evaluation Procedures for UMPC Mini-Tablet Devices	2015-10
248227 D01 v02r02	SAR Guidance for 802.11 (Wi-Fi) Transmitters	2015-10
690783 D01 v01r03	SAR Listings on Equipment Authorization Grants	2013-09
941225 D01 v03r01	SAR Measurement Procedures for 3G Devices	2015-10
447498 D02 v02r01	SAR Measurement Procedures for USB Dongle Transmitters	2015-10

TCB Council Presentations		
Name	**Description**	**Date**
RF Exposure Procedures Update	GSM/GPRS SAR	2013-10
RF Exposure Procedures	Overlapping LTE Bands	2015-04
RF Exposure Procedures	Bluetooth Duty Factor	2016-10
RF Exposure Procedures	DUT Holder Pertubations	2016-10
RF Exposure Procedures	HSUPA Configuration Update	2017-05
RF Exposure Procedures	802.11ax SAR Testing	2019-04
RF Exposure Procedures	SPLSR Hotspot Combination	2019-11
RF Exposure Procedures	LTE UL/DL Carrier Aggregation	2017-11
RF Exposure Procedures	LTE DL CA Test Exclusion	2018-04

KDB Guidance/Inquiry		
Name	**Description**	**Date**
511278	Resource Block Allocation for LTE Cat-M1	2019-04

3 SAR System and Procedures

3.1 SAR System Description

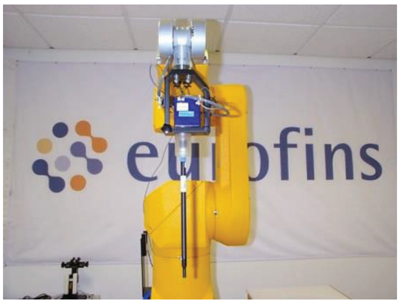
SAR System	
	

SAR System Components
– A standard high precision 6-axis robot (Stäubli TX=RX family) 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 Win7 profesional operating system 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

3.2 SAR System Components

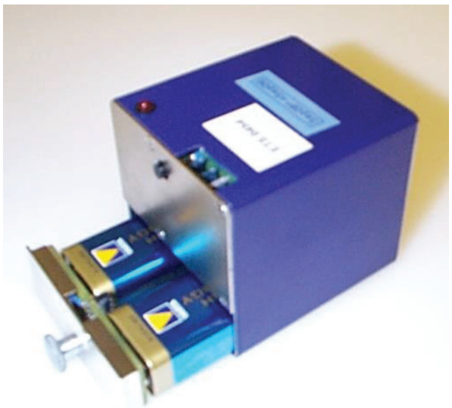
SAR Component - Robot

- The DASY5 system uses the high precision robots RX90BL type out of the newer series from Stäubli SA (France)
- High precision (repeatability 0.02 mm)
- High reliability (industrial design)
- Jerk-free straight movements
- Low ELF interference (the closed metallic construction shields against motor control fields)
- 6-axis controller



SAR Component - DAE

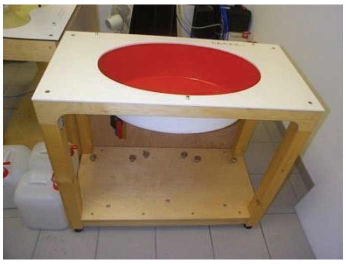
- The data acquisition electronics (DAE3) consists of a highly sensitive electrometer-grade preamplifier with auto-zeroing, a channel and gain-switching multi-plexer, a fast 16 bit AD-converter and a command decoder and control logic unit. Transmission to the measurement server is accomplished through an optical downlink for data and status information as well as an optical uplink for commands and the clock
- The mechanical probe mounting device includes two different sensor systems for frontal and sideways probe contacts. They are used for mechanical surface detection and probe collision detection. The input impedance of the DAE3 is 200M Ohm; the inputs are symmetrical and floating. Common mode rejection is above 80dB



SAR Component - Probe

- One dipole parallel, two dipoles normal to probe axis built-in shielding against static charges
- Frequency Range: 10 MHz to 6 GHz
- Linearity: ±0.2dB (30MHz to 6GHz)
- Directivity:
  - ±0.3 dB in HSL (rotation around probe axis)
  - ±0.5 dB in tissue material (rotation normal to probe axis)
- Dynamic Range: 5µW/g to > 100mW/g
- Dimensions:
  - Overall Length: 337mm (Tip: 20mm)
  - Tip Diameter: 2.5mm (Body: 12mm)
  - Distance from probe tip to dipole centers: 1mm

SAR Component – Twin Phantom	
– Material: Vinyl ester, fiberglass reinforced (VE-GF) – Shell Thickness: 2 ± 0.2 mm (6 ± 0.2 mm at ear point) – Three measurement areas: ▪ Left Hand ▪ Right Hand ▪ Flat Phantom – Length: 1000 mm – Width: 500 mm – Height: adjustable feet – Filling Volume: approx. 25 liters	

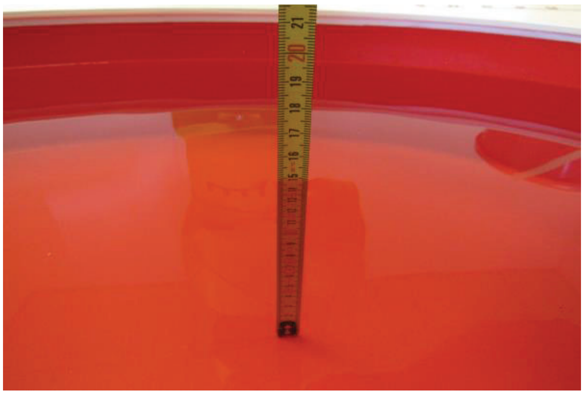
SAR Component – ELI Phantom	
– Intended for compliance testing of handheld and body-mounted wireless devices in the frequency range of 30 MHz to 6 GHz – Material: Vinyl ester, fiberglass reinforced (VE-GF) – Shell thickness: 2.0 ± 0.2 mm (bottom plate) – Major axis: 600 mm – Minor axis: 400 mm – Filling Volume: approx. 30 liters	

SAR Component – ELI Phantom	
– Is designed to cope with the different positions given in the standard – It has two scales for device rotation (with respect to the body axis) and device inclination (with respect to the line between the ear reference points) – The rotation centers for both scales is the ear reference point (ERP) – Is constructed of low-loss POM material having the following dielectric parameters: relative permittivity ε=3 and loss tangent δ=0.02	

SAR Component – Dipole 900 MHz – ELI Phantom	
– Symmetrical dipole with λ/4 balun – Frequency: 900 MHz – Return Loss: >20 dB at specified validation position – Power Capability: ▪ >100 W (f <1 GHz) ▪ >40 W (f >1 GHz) – Dipole length: 148.5 mm – Overall height: 340.0	

SAR Component – Dipole 1900 MHz – ELI Phantom	
– Symmetrical dipole with λ/4 balun – Frequency: 1900 MHz – Return Loss: >20 dB at specified validation position – Power Capability: ▪ >100 W (f <1 GHz) ▪ >40 W (f >1 GHz) – Dipole length: 67.7 mm – Overall height: 300.0	

SAR Component – SAM Twin Phantom Liquid Depth (FCC KDB 865664 D01)	
– The depth of tissue-equivalent liquid in a phantom must be ≥ 15.0 cm with ≤ 0.5 cm variation for SAR measurements ≤ 3 GHz and ≥ 10.0 cm with ≤ 0.5 cm variation for measurements > 3 GHz. These depths should ensure the SAR probe is immersed sufficiently in the tissue medium while scanning along the curved surfaces of the SAM phantom at various probe angles, with an acceptable separation between the top of the zoom scan volume and the liquid-air boundary above. The required liquid depth for typical SAR measurements is determined at the ERP location of the SAM phantom and at the center of the measurement region for a flat phantom.	

SAR Component – ELI Phantom Liquid Depth (FCC KDB 865664 D01)	
– The depth of tissue-equivalent liquid in a phantom must be ≥ 15.0 cm with ≤ 0.5 cm variation for SAR measurements ≤ 3 GHz and ≥ 10.0 cm with ≤ 0.5 cm variation for measurements > 3 GHz. These depths should ensure the SAR probe is immersed sufficiently in the tissue medium while scanning along the curved surfaces of the SAM phantom at various probe angles, with an acceptable separation between the top of the zoom scan volume and the liquid-air boundary above. The required liquid depth for typical SAR measurements is determined at the ERP location of the SAM phantom and at the center of the measurement region for a flat phantom.	

3.3 Tissue Liquid Validation

Tissue Simulating Liquid Target Values (FCC KDB 865664 D01)				
Target Frequency [MHz]	Head		Body	
	εr	σ [S/m]	εr	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
5800	35.3	5.27	48.2	6.00
Note1: Per FCC KDB 865664 D01 the dielectric parameters should be linearly interpolated between the closest pair of target frequencies to determine the applicable dielectric parameters corresponding to the device test frequency				
Note 2: Per FCC KDB 865664 D01 if the deviation from the target values are within 5 to 10 % the measured SAR values must be compensated for the tissue dielectric deviations				

DAK 3.5 Tissue Simulating Liquid System Components

DAK 3.5 System Tissue Validation Procedure (FCC KDB 865664 D01, IEEE 1528:2013)
1. The target frequency range is set in the measurement software
2. The DAK-System is calibrated with open termination
3. The DAK-System is calibrated with short termination using the shorting block of the system
4. The DAK-System is calibrated with load termination using distilled water
5. The Probe is put into the tissue simulating liquid inside the measurement phantom
6. The tissue simulating liquid parameters are measured over the target frequency range
7. The liquid parameters are interpolated in order to get the target parameters of the source target frequencies
8. The deviations $\Delta\varepsilon_r$ and $\Delta\sigma$ of the liquid parameters from the target parameters given by the FCC and IEEE 1528:2013 in % are calculated: $\Delta\epsilon_r[\%] = \frac{\epsilon_{r\ measured} - \epsilon_{r\ target}}{\epsilon_{r\ target}} \cdot 100$ $\Delta\sigma[\%] = \frac{\sigma_{measured} - \sigma_{target}}{\sigma_{target}} \cdot 100$
9. The deviations must be ≤ 5% according to FCC KDB 865664 D01 and ≤ 10% for IEEE 1528:2013
10. The liquid parameters are exported from the measurement software and imported to the DASY Software

3.4 Tissue Liquid Recipes

Body Tissue Simulating Liquids < 3 GHz					
Ingredient	M 750 weight (%)	M 900 weight (%)	M 1800 weight (%)	M 1900 weight (%)	M 2450 weight (%)
Water	51.7	50.75	70.17	69.79	68.64
Sugar	47.2	48.21	-	-	-
Cellulose	-	-	-	-	-
Salt	0.9	-	0.39	0.2	-
Preventol	0.1	0.1	-	-	-
DGBE	-	-	29.44	30	31.37

Head Tissue Simulating Liquids < 3 GHz					
Ingredient	HSL 750 weight (%)	HSL 900 weight (%)	HSL 1800 weight (%)	HSL 1900 weight (%)	HSL 2450 weight (%)
Water	41.1	40.29	55.24	55.41	55
Sugar	57.0	57.9	-	-	-
Cellulose	0.20	0.24	-	-	-
Salt	1.4	1.38	0.31	0.08	-
Preventol	0.2	0.18	-	-	-
DGBE	-	-	44.45	44.51	45

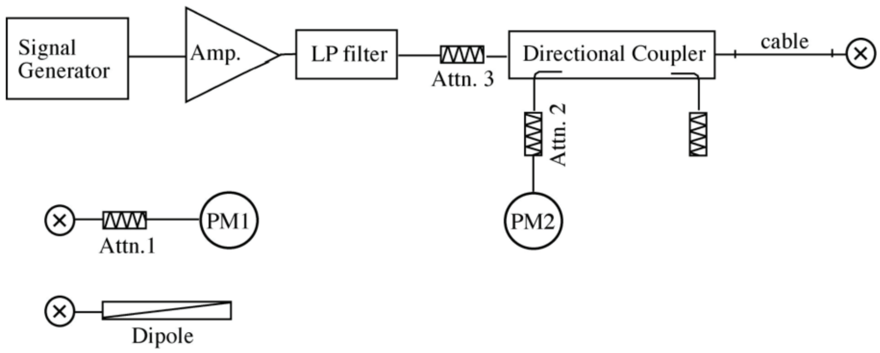
Ingredients	
Water	deionized water. resistivity ≥ 16 MΩ
Sugar	refined white sugar
Cellulose	Hydroxyethyl-cellulose
Salt	pure NaCl
Preventol	Preventol D-7
DGBE	Diethylenglycol-monobuthyl ether

Body Tissue Simulating Liquids > 3 GHz	
MBBL 3-6 GHz	Liquids are direct from Speag

Head Tissue Simulating Liquids > 3 GHz	
HBBL 3-6 GHz	Liquids are direct from Speag

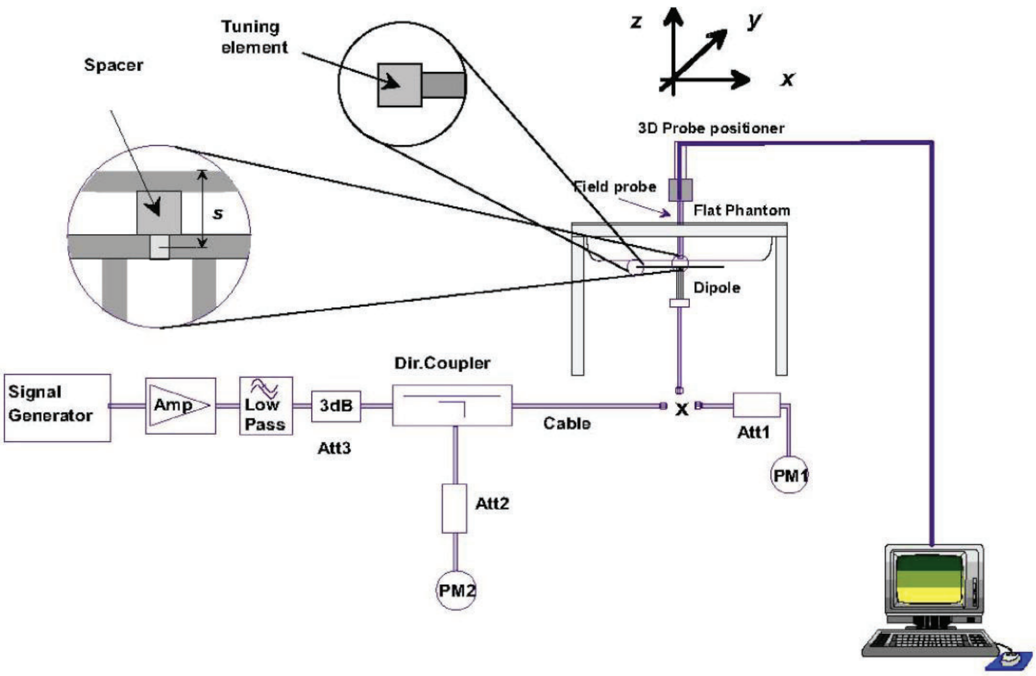
3.5 SAR System Validation

SAR System Validation Power Setup (FCC KDB 865664 D01, IEEE 1528:2013)



SAR System Validation Power Setup Procedure (FCC KDB 865664 D01, IEEE 1528:2013)	
1.	The power sensor PM1 is connected to the end of the feeding cable where the dipole is later connected
2.	The signal generator is set to the target frequency and the output power of the signal genetor is set to a value that the power sensor PM1 shows the target system validation power (e.g 250 mW or 100 mW)
3.	The reading of the power sensor PM2 is recorded
4.	The dipole is connected to the end of the feeding cable and placed under the phantom with the corresponding tissue simulating liquid
5.	The power level of the signal generator is readjusted until the reading of PM2 in step 3 is shown again

SAR System Validation Measurement (FCC KDB 865664 D01, IEEE 1528:2013)

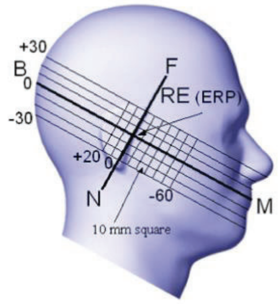
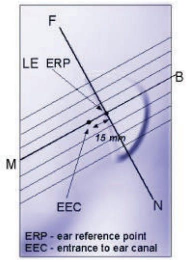


SAR System Validation Measurement Procedure (FCC KDB 865664 D01, IEEE 1528:2013)
Setup: 1. The system validation dipole is placed beneath the flat phantom (ELI phantom or flat phantom section of twin phantom) filled with the corresponding tissue simulating liquid of interest 2. A spacer is used to set the correct distance of the dipole from the phantom: From IEEE 1528:2013: s = 15 mm ± 0.2 mm for 300 MHz ≤ f ≤ 1000 MHz From IEEE 1528:2013: s = 10 mm ± 0.2 mm for 1000 MHz < f ≤ 6000 MHz 3. The power setup procedure is used to set the target feed power given in the calibration documentation of the validation dipole (e.g. 250 mW or 100 mW) Power reference Measurement: 4. At the center of the dipole area scan an initial power measurement is performed with the SAR probe in oder to determine the power drift during the validation measurement Area Scan: 5. A plane area parallel to the phantom surface is scanned using fixed grid spacing 6. The measurement values are interpolated in oder to find the peak SAR location inside the area 7. The cube for the zoom scan is centred at the location of the peak SAR location Zoom Scan: 8. The cube for the zoom scan is scanned using a fine 3 dimensional grid 9. The measurement values are interpolated and the average peak SAR value is calculated for the desired reference mass (e.g. 1-g or 10-g) Power Drift Measurement: 10. An other power measurement is performed at the same location as for step 4 11. The power difference between step 10 and 4 is calculated 12. According to FCC KDB 865664 D01 the power drift must be ≤ ± 5 % (or ≤ ± 0.2 dB) for the measurement to be valid Deviation Analysis: 13. The measured SAR values are normalized to 1 W input power (SAR values times 4 for 250 mW or times 10 for 100 mW input power) 14. The deviation in % from the SAR values given in the calibration sheet for the dipole and tissue simulating liquid is calculated $\Delta SAR[\%] = \frac{SAR_{measured} - SAR_{target}}{SAR_{target}} \cdot 100$ 15. Per FCC KDB 865664 D01 the device must be ≤ ± 10 % of the target values given in the calibration document of the dipole

3.6 SAR Head Positions

SAM Twin Phantom (IEEE 1528:2013)
SAM Phantom – Phantom shells for use with the test procedures in this recommended practice shall be manufactured using the CAD file of the SAM model – When used in a horizontal configuration, the SAM phantom shell is bisected along the mid-sagittal plane into right and left halves – Testing is required on both right and left sides – The perimeter sidewalls of each phantom half are extended to allow filling with liquid to a depth that is sufficient to minimize reflections from the upper surface – The liquid depth shall be measured from the ERP (inside the SAM phantom) to the air-liquid interface – shall be constructed from chemical-resistant, low-permittivity and low-loss material, with relative permittivity between 2 and 5; however, less than 2 is acceptable for frequencies up to 3 GHz – The shape of the phantom shell shall have a tolerance of less than ± 0.2 mm with respect to the SAM CAD file – In any area within the projection of the handset, the shell thickness shall be 2 mm, except for the ear and the extended perimeter walls; The tolerance on the shell thickness shall be ± 0.2 mm – In any area within the projection of the handset, the shell thickness shall be 2 mm, except for the ear and the extended perimeter walls; The tolerance on the shell thickness shall be ± 0.2 mm Flat Phantom – The minimum transverse dimensions (width and length) shall be used such that the SAR results are within 1% of a phantom with larger dimensions – For a half-wavelength dipole source, the length shall be at least 0.6 times the wavelength in air in the major dimension, and width shall be at least 0.4 times the wavelength in air in the minor dimension, with the bottom surface area larger than a corresponding ellipse – For 800 MHz to 6 GHz, the minimum dimensions of the flat phantom shall be 22.5 cm × 15 cm in the major and minor axes, respectively – The relative permittivity of the phantom shell material shall be between 2 and 5; however, less than 2 is acceptable below 3 GHz – The loss tangent of the phantom shell material shall be less than or equal to 0.05 – The thickness of the flat phantom bottom section shall be 2 mm. The thickness shall be uniform within a tolerance of ± 0.2 mm – When filled with liquid, the sagging of the phantom directly above the source (e.g., dipole) due to the weight of the liquid shall be less than 1% of a wavelength in air in the frequency range of 800 MHz to 6 GHz, and less than 0.5% of a wavelength in air at frequencies below 800 MHz

Head Reference Lines (IEEE 1528:2013)


Ear Reference Lines (IEEE 1528:2013)
 

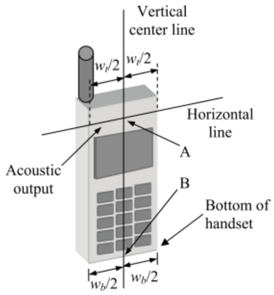
Test Positions (IEEE 1528:2013)
– two device test positions against the head phantom—the “cheek” position and the “tilt” position
– The device shall be tested in both positions on left and right sides of the SAM phantom

Cheek Position (IEEE 1528:2013)

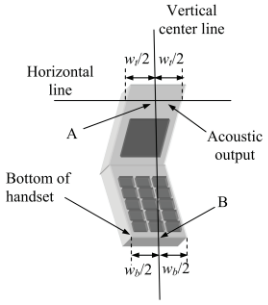
- The N-F line is in the plane defined by the handset vertical centerline and horizontal line
- Handset touches the pinna
- The handset vertical centerline is aligned with the Reference Plane

Procedure:

1. Ready the handset for talk operation, if necessary. For example, for handsets with a flip, swivel, or slide cover piece, open the cover if this is consistent with talk operation. If the handset can transmit with the cover closed, this configuration shall be tested also
2. Define two imaginary lines on the handset—the vertical centerline and the horizontal line. The vertical centerline passes through two points on the front side of the handset—the midpoint of the width wt of the handset at the level of the acoustic output [point A in Figure (a) and Figure (b)], and the midpoint of the width wb at the bottom of the handset (point B). The horizontal line is perpendicular to the vertical centerline and passes through the center of the acoustic output [see Figure (a)]. The horizontal line is also tangential to the face of the handset at point A. The two lines intersect at point A.

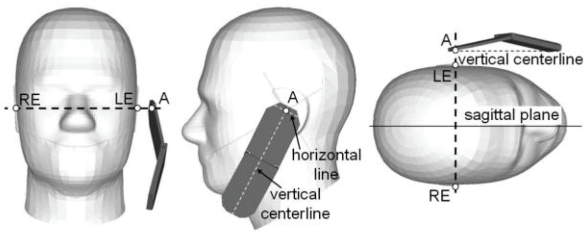


a) Fixed case

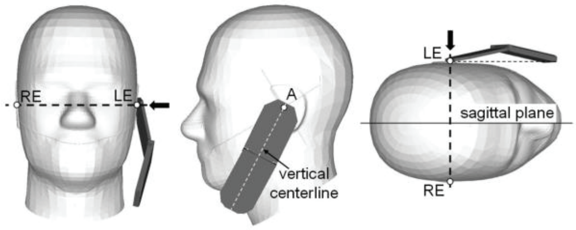


b) Clamshell case

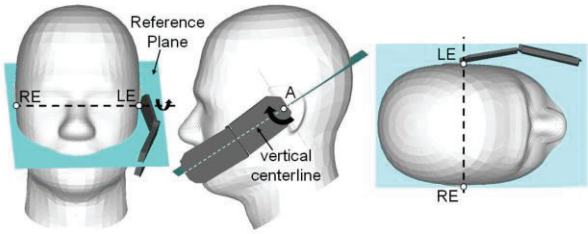
3. Position the handset close to the surface of the phantom such that point A is on the (virtual) extension of the line passing through points RE and LE on the phantom. The plane defined by the vertical centerline and the horizontal line of the handset is parallel to the sagittal plane of the phantom



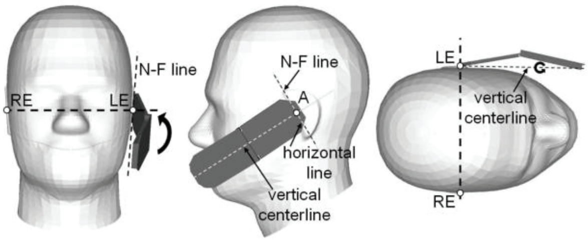
4. Translate the handset towards the phantom along the line passing through RE and LE until the handset touches the pinna



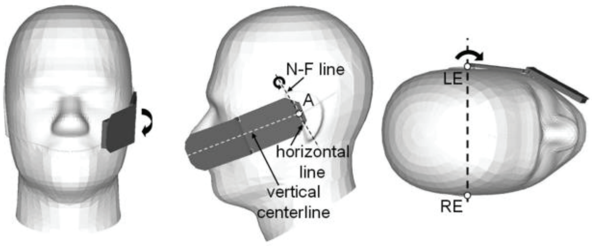
5. Rotate the handset around the (virtual) LE-RE line until the handset vertical centerline is in the Reference Plane



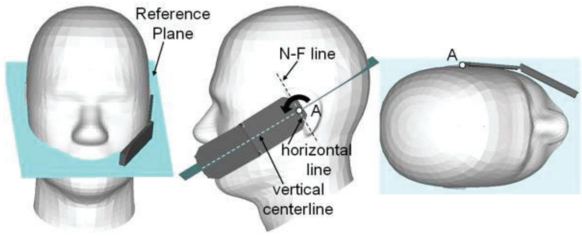
6. Rotate the handset around the vertical centerline until the plane defined by the handset vertical centerline and horizontal line is parallel to the N-F line, and translate the handset along the LE-RE line toward the phantom until handset touches the pinna

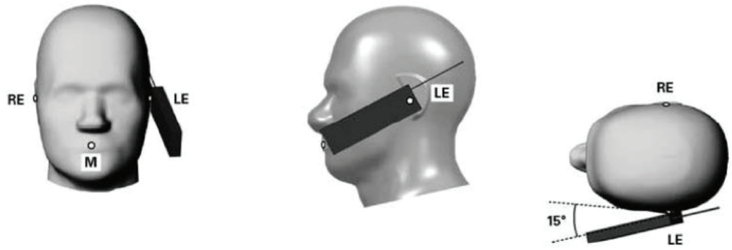


7. While keeping point A on the line passing through RE and LE, and maintaining the handset in contact with the pinna at the ERP, rotate the handset about the N-F line until any point on the handset is in contact with a phantom point below the pinna on the cheek

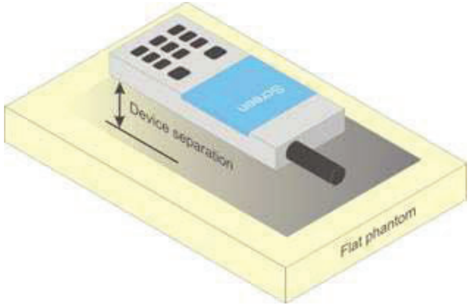
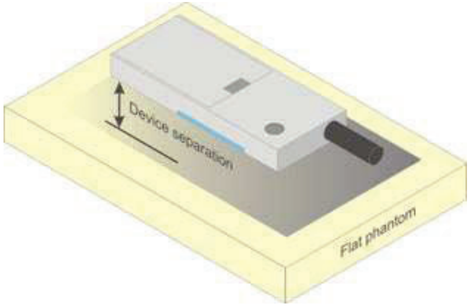


8. While keeping the handset in contact with the pinna, rotate the handset around a line perpendicular to the plane defined by the handset vertical centerline and horizontal line and passing through handset point A, until the handset vertical centerline is in the Reference Plane. Note that this step is necessary, as the handset may not be in the reference plane after step 7)



Tilt Position (IEEE 1528:2013)
Procedure: 1. Repeat the steps for the cheek position to place the device in the cheek position 2. While maintaining the orientation of the handset, move the handset away from the pinna along the line passing through RE and LE far enough to allow a rotation of the handset away from the cheek by 15° 3. Rotate the handset around the horizontal line by 15° 4. While maintaining the orientation of the handset, move the handset towards the phantom on the line passing through RE and LE until any part of the handset touches the ear. The tilt position is obtained when the contact point is on the pinna. If contact occurs at any location other than the pinna, e.g., the antenna at the back of the phantom head, the angle of the handset shall be reduced. In this case, the tilt position is obtained if any point on the handset is in contact with the pinna and a second point on the handset is in contact with the phantom, e.g., the antenna with the back of the head 

3.7 SAR Body Positions

Body-worn Positions (FCC KDB 447498 D01)
– Devices that support transmission while used with body-worn accessories must be tested for body worn accessory SAR compliance – Body SAR compliance is also tested with a flat phantom – SAR evaluation is required for body-worn accessories supplied with the host device – All body-worn accessories containing metallic components, either supplied with the product or available as an option from the device manufacturer, must be tested in conjunction with the host device to demonstrate compliance – Body-worn accessory SAR compliance must be based on a single minimum test separation distance for all wireless and operating modes applicable to each body-worn accessory used by the host, and according to the relevant voice and/or data mode transmissions and operations – A conservative minimum test separation distance for supporting off-the-shelf body-worn accessories – that may be acquired by users of consumer handsets should be used to test for body-worn accessory SAR compliance – This distance is determined by the handset manufacturer according to the typical body-worn accessories users may acquire at the time of equipment certification, but not more than 2.5 cm, to enable users to purchase aftermarket body-worn accessories with the required minimum separation – The selected test separation distance must be clearly explained in the SAR report to support the body-worn accessory test configurations – Devices that are designed to operate on the body of users using lanyards and straps or without requiring additional body-worn accessories must be tested for SAR compliance using a conservative minimum test separation distance ≤ 5 mm to support compliance
 

3.8 SAR Measurement Procedure

Step 1: Power Reference Measurement (FCC KDB 865664 D01, IEEE 1528:2013)
1. The probe is positioned at the closest distance to the surface of the phantom
2. A power measurement is performed as later reference for the second power drift measurement at the same position

Step 2: Area Scan (FCC KDB 865664 D01, IEEE 1528:2013)

1. An area larger than all radiating structures and antennas of the equipment under test is defined
2. The grid spacing and distance to the phantom surface is selected according to the requirements given in FCC KDB 865664 D01

	≤ 3 GHz	> 3 GHz
Maximum distance from closest measurement point (geometric center of probe sensors) to phantom surface	5 mm ± 1 mm	$\frac{1}{2} \cdot \delta \cdot \ln(2)$ mm ± 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.	

Settings applied: for frequencies < 3 GHz: $\Delta x = \Delta y = 10$ mm; $\Delta z = 4$ mm (Note 1)

Settings applied: for frequencies > 3 GHz: $\Delta x = \Delta y = 5$ mm; $\Delta z = 2$ mm (Note 2)

3. At each grid point a measurement is performed until all points of the grid are measured
4. The values are interpolated an the location of the peak SAR value is determined
5. If a location closer than ½ the zoom scan volume to the edges is determined, the area is extended

Note 1: According the DASY 5.2 Manual a distance of the Probe Sensor to the Phantom Surface should be between 4 mm up to 3 GHz

Note 2: According the DASY 5.2 Manual a distance of the Probe Sensor to the Phantom Surface should be between 1.5 and 2.0 mm above 3 GHz

½ · δ · ln(2) (IEEE 1528:2013)

Frequency [MHz]	½ · δ ·ln(2) [mm]
3000	4.8
4000	3.3
5000	2.5
5200	2.4
5400	2.3
5600	2.2
5800	2.1
6000	2.0

Note 1: According the DASY 5.2 Manual a distance of the Probe Sensor to the Phantom Surface should be between 1.5 and 2.0 mm

Step 3: Zoom Scan (FCC KDB 865664 D01, IEEE 1528:2013)

1. The zoom scan is initially performed at the location of the highest peak SAR in the area scan
2. For the zoom scan a 3d cube is used with grid settings as required from FCC KDB 865664 D01:

			≤ 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·$\Delta z_{Zoom}(n-1)$ mm	
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 IEEE Std 1528-2013 for details.

* When zoom scan is required and the *reported* SAR from the *area scan based 1-g SAR estimation* procedures of KDB Publication 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.

Settings applied: for frequencies < 3 GHz: Δx = Δy = Δz = 5 mm; volume x,y,z = 30 mm

Settings applied: for frequencies > 3 GHz: Δx = Δy = Δz = 2 mm; volume x,y,z = 30 mm

3. The measured field strength values are interpolated and the average SAR value is calculated
4. When the 1-g SAR is within 2 dB of the SAR limit, additional zoom scans are performed for other peaks within 2 dB of the highest SAR peak
5. The determined 1-g and 10-g average SAR values are recorded for all determined SAR locations

Step 4: Power Drift Measurement (FCC KDB 865664 D01, IEEE 1528:2013)

1. At the same location as in step 1 the power measurement is repeated
2. The power drift is calculated from the values measured in step 4 (M_{step4}) and step 1 (M_{step1}) as

   Deviation = M_{step4} / M_{step1}
3. The drift in % is calculated as

   $10 \cdot \log_{10}(\text{Deviation})$ [dB]
4. The drift shall be ≤ ± 5 % or ≤ $10 \cdot \log_{10}(1.05) = 0.2$ dB or ≤ $10 \cdot \log_{10}(0.95) = -0.2$ dB

3.9 SAR Equipment List

SAR Test Equipment					
Description	Manufacturer	Model	Identifier	Cal. Date	Cal. Due
Stäubli Robot	Stäubli	RX90B L	EF00271	functional test	functional test
Stäubli Robot Controller	Stäubli	CS7MB	EF00272	functional test	functional test
DASY 5.2 Measurement Server	Schmid & Partner	-	EF00273	functional test	functional test
Control Pendant	Stäubli	-	EF00274	functional test	functional test
Dell Computer	Schmid & Partner	Intel	EF00275	functional test	functional test
Data Acquisition Electronics	Schmid & Partner	DAE3V1	EF00276	2020-09	2021-09
Dosimetric E-Field Probe	Schmid & Partner	EX3DV4	EF00826	2020-09	2021-09
SAM Twin phantom	Schmid & Partner	V 4.0	EF00286	functional test	functional test
Oval flat phantom	Schmid & Partner	ELI4	EF00289	functional test	functional test
System Validation Kit	Schmid & Partner	D300V2	EF00299	2018-09	2021-09
System Validation Kit	Schmid & Partner	D450V2	EF00300	2018-09	2021-09
System Validation Kit	Schmid & Partner	D750V3	EF00946	2020-09	2023-09
System Validation Kit	Schmid & Partner	D900V2	EF00281	2018-09	2021-09
System Validation Kit	Schmid & Partner	D1750V2	EF00947	2020-09	2023-09
System Validation Kit	Schmid & Partner	D1800V2	EF00282	2018-09	2021-09
System Validation Kit	Schmid & Partner	D1900V2	EF00283	2018-09	2021-09
System Validation Kit	Schmid & Partner	D2450V2	EF00284	2018-09	2021-09
System Validation Kit	Schmid & Partner	D2600V2	EF00948	2020-09	2023-09
System Validation Kit	Schmid & Partner	D5GHzV2	EF00827	2020-09	2023-09
DAK Thermometer (-20..110°C)	Schmid & Partner	DTM3000	EF00967	2021-03	2022-03
Mounting Device	Schmid & Partner	V3.1	EF00287	functional test	functional test
Millivoltmeter	R&S	URV5	EF00126	2019-07	2022-07
Power sensor	R&S	NRV-Z1	EF00127	2020-07	2022-07
Power sensor	R&S	NRV-Z2	EF00003	2020-07	2022-07
Spectrum- and Network-Analyzer	R&S	FSMS26	EF00005	no certification testing	no certification testing
Signal generator	R&S	SME 03	EF00169	functional test	functional test
DAK Probe Stand	Schmid & Partner	SM DAK 300 AA	EF00944	no calibration required	no calibration required
DAK Probe (200MHz-20GHz)	Schmid & Partner	DAK-3.5	EF00945	2020-09	2021-09
DAK Measurement Software	Schmid & Partner	DAK v2.6.0.5	EF00965	no calibration required	no calibration required
DAK Verification Kit	Schmid & Partner	SL AAH U16 BD	EF01128	no calibration required	no calibration required

3.10 Other Equipment List

Test Equipment					
Description	Manufacturer	Model	Identifier	Cal. Date	Cal. Due
R&S	Communication tester	CMW500	EF00677	2021-02	2022-02
R&S	Communication tester	CMW290	EF01367	2020-06	2021-06
ETS-Lindgren	Power Sensor	7002-006	EF00934	2020-07	2021-07

3.11 SAR Measurement Uncertainty

Measurement Uncertainty (IEEE 1528)							
Error Description	Uncertainty Value	Probability Distribution	Div.	ci (1g)	ci (10g)	Std. Unc. 1 g	Std. Unc. 10 g
Measurement System							
Probe Calibration	±6.55%	N	1	1	1	±6.55%	±6.55%
Axial Isotropy	±4.7%	R	$\sqrt{3}$	0.7	0.7	±1.9%	±1.9%
Hemispherical Isotropy	±9.6%	R	$\sqrt{3}$	0.7	0.7	±3.9%	±3.9%
Linearity	±4.7%	R	$\sqrt{3}$	1	1	±2.7%	±2.7%
Modulation Response	±2.4%	R	$\sqrt{3}$	1	1	±1.4%	±1.4%
System Detection Limits	±1.0%	R	$\sqrt{3}$	1	1	±0.6%	±0.6%
Boundary effects	±2.0%	R	$\sqrt{3}$	1	1	±1.2%	±1.2%
Readout Electronics	±0.3%	N	1	1	1	±0.3%	±0.3%
Response Time	±0.8%	R	$\sqrt{3}$	1	1	±0.5%	±0.5%
Integration Time	±2.6%	R	$\sqrt{3}$	1	1	±1.5%	±1.5%
RF Ambient Noise	±3.0%	R	$\sqrt{3}$	1	1	±1.7%	±1.7%
RF Ambient Reflections	±3.0%	R	$\sqrt{3}$	1	1	±1.7%	±1.7%
Probe Positioner	±0.8%	R	$\sqrt{3}$	1	1	±0.5%	±0.5%
Probe Positioning	±6.7%	R	$\sqrt{3}$	1	1	±3.9%	±3.9%
Post processing	±4.0%	R	$\sqrt{3}$	1	1	±2.3%	±2.3%
Test Sample Related							
Device Holder	±3.6%	N	1	1	1	±3.6%	±3.6%
Test Sample Positioning	±2.9%	N	1	1	1	±2.9%	±2.9%
Power Scaling	±0%	R	$\sqrt{3}$	1	1	±0%	±0%
Power Drift	±5.0%	R	$\sqrt{3}$	1	1	±2.9%	±2.9%
Phantom and Setup Related							
Phantom Uncertainty	±7.9%	R	$\sqrt{3}$	1	1	±4.6%	±4.6%
SAR correction	±1.9%	R	$\sqrt{3}$	1	0.84	±1.1%	±0.9%
Liquid conductivity (measured)	±2.5%	N	1	0.78	0.71	±2.0%	±1.8%
Liquid permittivity (measured)	±2.5%	N	1	0.26	0.26	±0.1%	±0.1%
Temperature uncertainty - Conductivity	±5.2%	R	$\sqrt{3}$	0.78	0.71	±2.3%	±2.1%
Temperature uncertainty - Permittivity	±0.8%	R	$\sqrt{3}$	0.23	0.26	±0.1%	±0.1%
Combined Standard Uncertainty						±12.8%	±12.7%
Expanded Standard Uncertainty						**±25.6%**	**±25.4%**

4 General Evaluation Guidance and Procedures

4.1 SAR Limits

Exposure Environments (FCC and ISED)	
General Population/ Uncontrolled Environment	Defined as locations where there is the exposure of individuals who has no knowledge or control of their exposure
Occupational/ Controlled Environment	Defined as locations where there is exposure that may be incurred by persons who are aware of the potential for exposure

SAR Limits (FCC and ISED)		
Exposure Condition	General Population	Occupational
Spatial Peak SAR (1-g) (Brain/Body/Arms/Legs)	1.60 W/kg	8.00 W/kg
Spatial Average SAR (Whole Body)	0.08 W/kg	0.40 W/kg
Spatial Peak SAR (10-g) (Hands/Feet/Ankle/Wrist)	4.00 W/kg	20.00 W/kg

4.2 SAR Evaluation for Head

SAR Evaluation for Head (FCC KDB 447498 D01)

– Devices that are designed to transmit next to the ear and operate according to the handset procedures in IEEE Std 1528-2013, or conditions described in the published RF exposure KDB procedures, must be tested using the SAM phantom defined in IEEE Std 1528-2013

– When antennas are near the bottom of a handset and the peak SAR location is located in regions of the SAM phantom where SAR probe access can be limited, the procedures in KDB Publication 648474 D04 must be applied

– Other head exposure conditions, for example, in-front-of the face, should be tested using a flat phantom according to the required published RF exposure KDB procedures

4.3 SAR Evaluation for body-worn accessory

SAR Evaluation for body-worn accessory (FCC KDB 447498 D01)

– Body SAR compliance is also tested with a flat phantom

– For devices with irregular shapes or form factors that do not conform to a flat phantom, and/or unusual operating configurations and exposure conditions, a KDB inquiry is also required to determine the appropriate SAR measurement procedures

Devices

– Devices that support transmission while used with body-worn accessories must be tested for bodyworn accessory SAR compliance

Accessories

– All body-worn accessories containing metallic components, either supplied with the product or available as an option from the device manufacturer, must be tested in conjunction with the host device to demonstrate compliance

– Body-worn accessories that do not contain metallic or conductive components may be tested according to worst-case exposure configurations, typically according to the smallest test separation distance required for the group of body-worn accessories with similar operating and exposure characteristics

– Body-worn accessory SAR compliance must be based on a single minimum test separation distance for all wireless and operating modes applicable to each body-worn accessory used by the host, and according to the relevant voice and/or data mode transmissions and operations

– If a body-worn accessory supports voice only operations in its normal and expected use conditions (for example, beltclips and holsters for cellphones), testing of data mode for body-worn compliance is not required

– A conservative minimum test separation distance for supporting off-the-shelf body-worn accessories that may be acquired by users of consumer handsets should be used to test for body-worn accessory This distance is determined by the handset manufacturer according to the typical body-worn accessories users may acquire at the time of equipment certification, but not more than 2.5 cm The selected test separation distance must be clearly explained in the SAR report to support the body-worn accessory test configurations – Devices that are designed to operate on the body of users using lanyards and straps or without requiring additional body-worn accessories must be tested for SAR compliance using a conservative minimum test separation distance ≤ 5 mm to support compliance – Users must be fully informed of the operating requirements and restrictions, to the extent that the typical user can easily understand the information, to acquire the required body-worn accessories to maintain compliance

4.4 SAR Evaluation for Extremities

SAR Evaluation for Extremities (FCC KDB 447498 D01)
– Devices that are designed or intended for use on extremities, or mainly operated in extremity only exposure conditions, i.e., hands, wrists, feet and ankles, may require extremity SAR evaluation – When extremity SAR testing is required, a flat phantom must be used if the exposure condition is more conservative than the actual use conditions otherwise, a KDB inquiry is required to determine the phantom and test requirements – When the device also operates in close proximity to the user's body, SAR compliance for the body is also required – The 1-g body and 10-g extremity SAR Test Exclusion Thresholds should be applied to determine SAR test requirements – For devices with irregular shapes or form factors that do not conform to a flat phantom, and/or unusual operating configurations and exposure conditions, a KDB inquiry is also required to determine the appropriate SAR measurement procedures – when simultaneous transmission applies to extremity exposure, the simultaneous transmission SAR test exclusion provisions should be applied – When simultaneous transmission SAR measurement is required, the enlarged zoom scan and volume scan post-processing procedures in KDB Publication 865664 D01 should be applied

4.5 Required test channels

Required SAR Test Channels (FCC KDB 447498 D01)

When the frequency channels required for SAR testing are not specified in the published RF exposure KDB procedures, the following should be applied to determine the number of required test channels:

$$N_c = Round\left[\sqrt{100 \cdot \frac{f_{high} - f_{low}}{f_c}} \cdot \left(\frac{f_c}{100}\right)^{0.2}\right]$$

where:

N_c: number of test channels, rounded to the nearest integer

f_{high}: highest channel frequencies within the transmission band in MHz

f_{low}: lowest channel frequencies within the transmission band in MHz

f_c: mid-band channel frequency in MHz

4.6 Maximum output power and tune-up tolerance

Maximum rated output power and tune-up tolerance (FCC KDB 447498 D01)
– The maximum output power and tolerance allowed for production units should be used to determine RF exposure test exclusion and compliance – Each device must be evaluated for SAR compliance in the required operating modes and test configurations, at the maximum rated output power and within the tune-up tolerance range specified for the product – SAR evaluation must be performed at power level not more than 2 dB lower than the maximum tune-up tolerance limit – The range of expected maximum output power variations from the rated nominal maximum output power specified for the product or wireless mode is referred to as the tune-up tolerance in this document. All devices must be tested within the tune-up tolerance specification range

Maximum source-based time-averaged conducted output power (KDB 865664 D01, TCB Council 2016-10)
– RF exposure compliance must be determined at the maximum average power level according to source-based time-averaging requirements – Time-averaged maximum conducted output power applies to SAR – When SAR evaluation is required to determine compliance, the duty factor established in the SAR analysis may be applied to scale the measured SAR

4.7 Reported SAR

Reported SAR according (FCC KDB 447498 D01)

Measured SAR values must be scales to the maximum tune-up tolerance limit. The results are referred to as reported SAR values:

$$SAR_{Reported}\left[\frac{W}{kg}\right] = SAR_{Measured}\left[\frac{W}{kg}\right] \cdot \frac{Power_{Maximum\ including\ tune-up\ tolerance}[mW]}{Power_{Actual\ for\ measurement}[mW]}$$

Reported SAR Duty Factor Scaling (FCC KDB 248227 D01)

The reported SAR values must be scales to the maximum duty factor specified for production units. The results are referred to as scaled reported SAR values:

$$SAR_{Reported\ \ Scaled}\left[\frac{W}{kg}\right] = SAR_{Reported}\left[\frac{W}{kg}\right] \cdot \frac{1}{Duty\ Factor}$$

4.8 Standalone SAR Test Exclusion

Standalone SAR test exclusion (FCC KDB 447498 D01)
Input: 1. P: Source-based time-averaged maximum conducted output power of RF channel requiring evaluation 2. d: Minimum test separation distance required for exposure conditions (Note 1, 2) 3. f: RF channel frequency Test exclusion power level calculation: 1. Frequency 100 MHz to 6 GHz, Test separation distance ≤ 50 mm: 1-g SAR: $P[mW] = 3.0 \cdot \frac{d[mm]}{\sqrt{f[GHz]}}$ 10-g SAR: $P[mW] = 7.5 \cdot \frac{d[mm]}{\sqrt{f[GHz]}}$ When test separation distance is < 5 mm, a distance of 5 mm is applied to determine test exclusion 2. Frequency 100 MHz to 6 GHz, Test separation distance > 50 mm: 1-g SAR: (100 – 1500 MHz) $P[mW] = \left(3.0 \cdot \frac{50\,mm}{\sqrt{f[GHz]}}\right) + \left[(d[mm] - 50\,mm) \cdot \frac{f[MHz]}{150}\right]$ 1-g SAR: (>1500 – 6000 MHz) $P[mW] = \left(3.0 \cdot \frac{50\,mm}{\sqrt{f[GHz]}}\right) + [(d[mm] - 50\,mm) \cdot 10]$ 10-g SAR: (100 – 1500 MHz) $P[mW] = \left(7.5 \cdot \frac{50\,mm}{\sqrt{f[GHz]}}\right) + \left[(d[mm] - 50\,mm) \cdot \frac{f[MHz]}{150}\right]$ 10-g SAR: (>1500 – 6000 MHz) $P[mW] = \left(7.5 \cdot \frac{50\,mm}{\sqrt{f[GHz]}}\right) + [(d[mm] - 50\,mm) \cdot 10]$ 3. Frequency < 100 MHz: 1-g SAR: (> 50 and <200 mm) $P[mW] = \left\{\left(3.0 \cdot \frac{50\,mm}{\sqrt{0.1}}\right) + \left[(d[mm] - 50\,mm) \cdot \frac{100}{150}\right]\right\} \cdot \left[1 + \log\left(\frac{100}{f[MHz]}\right)\right]$ 1-g SAR: (≤ 50 mm) $P[mW] = \left\{\left(3.0 \cdot \frac{50\,mm}{\sqrt{0.1}}\right) + \left[(d[mm] - 50\,mm) \cdot \frac{100}{150}\right]\right\} \cdot \left[1 + \log\left(\frac{100}{f[MHz]}\right)\right] \cdot \frac{1}{2}$ 10-g SAR: (> 50 and <200 mm) $P[mW] = \left\{\left(7.5 \cdot \frac{50\,mm}{\sqrt{0.1}}\right) + \left[(d[mm] - 50\,mm) \cdot \frac{100}{150}\right]\right\} \cdot \left[1 + \log\left(\frac{100}{f[MHz]}\right)\right]$ 10-g SAR: (≤ 50 mm) $P[mW] = \left\{\left(7.5 \cdot \frac{50\,mm}{\sqrt{0.1}}\right) + \left[(d[mm] - 50\,mm) \cdot \frac{100}{150}\right]\right\} \cdot \left[1 + \log\left(\frac{100}{f[MHz]}\right)\right] \cdot \frac{1}{2}$ 4. If the source-based time-averaged maximum conducted output power is lower or equal than the test exclusion power level no SAR testing will be required
Note 1: Minimum test separation distance is determined by the smallest distance from the antenna and radiating structures or outer surface of the device, according to the host form factor, exposure conditions and platform requirements, to any part of the body or extremity of a user or bystander Note 2: To qualify for SAR test exclusion, the test separation distances applied must be fully explained and justified, typically in the SAR measurement or SAR analysis report, by the operating configurations and exposure conditions of the transmitter and applicable host platform requirements, according to the required published RF exposure KDB procedures

Standalone SAR test exclusion (ISED RSS-102)
Input: 1. Output power level; shall be the higher of the maximum conducted or equivalent isotropically radiated power (e.i.r.p.) source-based, time-averaged output power 2. Minimum test separation distance D required for exposure conditions (Note) 3. RF channel frequency Test exclusion power level calculation: 1. Use linear interpolation of frequency and Separation distance in order to determine the excemption power level that applies to the test frequency and distance 2. If the output power level of the device is lower or equal than the excemption power level no SAR testing will be required
Note: When test separation distance is < 5 mm, a distance of 5 mm is applied to determine test exclusion

Excemption Power Limits [mW] (ISED RSS-102)

Freq. [MHz]	Separation Distance [mm]									
	≤ 5	10	15	20	25	30	35	40	45	≥ 50
≤ 300	71	101	132	162	193	223	254	284	315	345
450	52	70	88	106	123	141	159	177	195	213
835	17	30	42	55	67	80	92	105	117	130
1900	7	10	18	34	60	99	153	225	316	431
2450	4	7	15	30	52	83	123	173	235	309
3500	2	6	16	32	55	86	124	170	225	290
5800	1	6	15	27	41	56	71	85	97	106

Note: For limb-worn devices where the 10 gram value applies, the exemption limits for routine evaluation in the Table are multiplied by a factor of 2.5

4.9 SAR Value Estimation

Estimated SAR (FCC KDB 447498 D01)

Input:

1. P: Source-based time-averaged maximum conducted output power of RF channel requiring evaluation
2. d: Minimum test separation distance required for exposure conditions (Note)
3. f: RF channel frequency

Estimated SAR calculation:

1. Test separation distance ≤ 50 mm:

1-g SAR: $$SAR_{Estimated}\left[\frac{W}{kg}\right] = \frac{P[mW]}{d[mm]} \cdot \frac{\sqrt{f[GHz]}}{7.5}$$

10-g SAR: $$SAR_{Estimated}\left[\frac{W}{kg}\right] = \frac{P[mW]}{d[mm]} \cdot \frac{\sqrt{f[GHz]}}{18.75}$$

2. Test separation distance > 50 mm:

1-g SAR: $$SAR_{Estimated}\left[\frac{W}{kg}\right] = 0.4$$

10-g SAR: $$SAR_{Estimated}\left[\frac{W}{kg}\right] = 1.0$$

Note: Minimum test separation distance is determined by the smallest distance from the antenna and radiating structures or outer surface of the device, according to the host form factor, exposure conditions and platform requirements, to any part of the body or extremity of a user or bystander

4.10 Simultaneous SAR Test Exclusion

Simultaneous Transmitter SAR test exclusion (FCC KDB 447498 D01)
Method 1 – Sum of SAR: 1. The SAR values from the simultaneous transmitting radios are selected 2. If an excluded radio transmitter participates in the multi-transmitter mode, the SAR value must be estimated 3. The reported SAR values from the simultaneous transmitting radios are added 4. If the sum of SAR values is below the limit no further SAR testing is required
Method 2 – SAR to Peak Location Separation Ratio (SPLSR) 1. The SAR values from the simultaneous transmitting radios are selected 2. If an excluded radio transmitter participates in the multi-transmitter mode, the SAR value must be estimated 3. From the various transmitters participating in the multi-transmitter mode, all pairs of two transmitters are evaluated (e.g. for three simultaneous transmitters = 1 and 2, 2 and 3, 1 and 3) 4. For the transmitter pair under evaluation the location of the hotspot is determined Measured SAR: The location of the hotspot as given in the SAR measurement results Estimated SAR: The center of the transmitter antenna 5. With the two reported SAR values SAR_1 and SAR_2 and the separation distance r the SPLSR is calculated: $SPLSR = \frac{\sqrt{(SAR_1 + SAR_2)^3}}{R}$ 6. If the result is below the exclusion value the pair is excluded 1-g SAR: $SPLSR \leq 0.04$ 10-g SAR: $SPLSR \leq 0.10$ 7. All antenna pair that do not qualify for test exclusion must be tested

4.11 General SAR Test Reduction

General SAR test reduction (FCC KDB 447498 D01)
1. SAR is measured for the mid-band or highest output power channel 2. Testing of the other required channels within the operating mode of a frequency band is not required if the the reported 1-g or 10-g SAR of the test channel in step 1 is: 1-g SAR (Band ≤ 100 MHz): $SAR_{Reported} \leq 0.8 \frac{W}{kg}$ 1-g SAR (100 MHz < Band < 200 MHz): $SAR_{Reported} \leq 0.6 \frac{W}{kg}$ 1-g SAR (Band ≥ 200 MHz): $SAR_{Reported} \leq 0.4 \frac{W}{kg}$ 10-g SAR (Band ≤ 100 MHz): $SAR_{Reported} \leq 2.0 \frac{W}{kg}$ 10-g SAR (100 MHz < Band < 200 MHz): $SAR_{Reported} \leq 1.5 \frac{W}{kg}$ 10-g SAR (Band ≥ 200 MHz): $SAR_{Reported} \leq 1.0 \frac{W}{kg}$

4.12 SAR Measurement Variability

SAR Measurement Variability (FCC KDB 865664 D01)
– Repeated measurement is not required when the original highest measured SAR is < 0.80 W/kg – When the original highest measured SAR is ≥ 0.80 W/kg, repeat that measurement once – 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 – 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 – The same procedures should be adapted for measurements according to extremity and occupational exposure limits by applying a factor of 2.5 for extremity exposure and a factor of 5 for occupational exposure to the corresponding SAR thresholds
Procedure: 1. Additional measurements are repeated after the completion of all measurements requiring the same head or body tissue-equivalent medium in a frequency band 2. The test device should be returned to ambient conditions (normal room temperature) with the battery fully charged 3. The device is re-mounted on the device holder for the repeated measurement(s) using the same measurement settings and configuration as for the initial SAR measurement

4.13 SAR Measurement Uncertainty

SAR Measurement Uncertainty (FCC KDB 865664 D01)
– 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 – SAR measurement uncertainty analysis is required in SAR reports only when the highest measured SAR in a frequency band is ≥ 1.5 W/kg for 1-g SAR – The procedures described in IEEE Std 1528-2013 should be applied – The expanded SAR measurement uncertainty must be ≤ 30%, for a confidence interval of k = 2

4.14 SAR DUT Holder Perturbations

SAR DUT Holder Perturbations (FCC TCB Council 2016-10)
– When the highest reported SAR of an antenna is > 1.2 W/kg (1-g) or 3.0 (10-g), holder perturbation verification is required for each antenna, using the highest SAR configuration among all applicable frequency bands – in the same exact device and holder positions used for head and body SAR measurements; i.e. same device/button locations in the holder – a KDB inquiry is required if the highest reported SAR for each antenna, adjusted for increases in holder perturbation, would introduce noncompliance conditions or noticeably high differences due to perturbation
Procedure: 1. For each frequency band and exposure condition the highest reported SAR is determined for each antenna 2. If the reported SAR is above the threshold value the procedure given in E.4.1.1 of IEEE 1528:2013 is followed for holder perturbation analysis 3. The SAR tolerance is calculated $SAR_{tolerance}[\%] = \frac{SAR_{with\ holder} - SAR_{without\ holder}}{SAR_{with\ holder}} \cdot 100$ 4. If the SAR tolerance is negative which means that the SAR value without DUT holder is larger than the SAR value with DUT holder, the reported SAR value is corrected by the SAR tolerance in order to take the decrease in SAR value because of the DUT holder into account. $SAR_{Reported\ with\ DUT\ holder\ perturbations}\left[\frac{W}{kg}\right] = SAR_{Reported}\left[\frac{W}{kg}\right] \cdot \left(1 - \frac{SAR_{tolerance}[\%]}{100}\right)$

4.15 SAR Reporting

General RF-Exposure Reporting Requirements (FCC KDB 865664 D02)
– The operating modes and exposure conditions of all wireless technologies applicable to the equipment approval must be clearly described 1. Nominal and maximum output power of all wireless modes and frequency bands of production units should be specified; Tune-up tolerances should also be included when it is required for equipment authorization otherwise, the maximum power allowed for production units should be identified. When multiple maximum output power levels are specified for a wireless or operating mode; for example, different time slots, data rates or modulation requirements, such as GPRS, EDGE, 802.11, WiMax and various 3GPP implementations, the maximum output power of each configuration should be identified separately 2. Antenna dimensions and separation distances should be illustrated in photos and/or diagrams 3. Voice and data mode transmission requirements in all supported operating configurations and exposure conditions for standalone and simultaneous transmission operations 4. Device implementation and operating requirements that can influence the RF exposure evaluation; for example, MPR, testing duty factor for TDD systems, power reduction requirements and multiple transmission configurations, such as data rate, data mode, channel bandwidth and modulation etc 5. Accessories supplied with the device or available as options from the device manufacturer or provisions for supporting other after-market accessories that can influence the RF exposure evaluation 6. Accessories supplied with the device or available as options from the device manufacturer or provisions for supporting other after-market accessories that can influence the RF exposure evaluation 7. Optional antennas – The device test setup and operating configurations used to establish transmission in various wireless modes should be documented; the information should include at least the following 1. The test setup, measurement, numerical simulation or analysis procedures and KDB numbers of published RF exposure KDB procedures applied to test the device, include latest applicable TCB workshop guidance, 2. Test guidance and other considerations provided through specific KDB inquiries to manufacturers and test labs should be fully described in test reports to support the test results. KDB tracking numbers should not be identified in test reports 3. Source-based time-averaging duty factors that are inherent to device transmissions or applied separately to the measured results must be clearly explained in the test reports 4. When test reduction and exclusion are applied, justifications according to the published RF exposure KDB procedures or KDB inquiries are required 5. Except for generic test setup photos, other diagrams and illustrations should include proper explanations and descriptions to support the test setup and measurement results 6. The test and supporting equipment or numerical simulation tools used to test the device should be uniquely identified in test reports, including actual calibration dates, required calibration interval and calibration status or software release versions. Equipment and apparatuses that are not used in the tests, except when clearly noted, should not be listed

SAR Reporting Requirements (FCC KDB 865664 D02)
– SAR system validation status and system verification results should be documented in a separate section of the SAR report, or as an attachment, to confirm measurement accuracy – Conducted output power measurements are required to support the SAR results and for scaling results to the maximum tune-up tolerance or production limit – When multiple maximum output power levels are applied to different transmission configurations; for example, due to time slot, data rate, transmission protocol or signal modulation requirements, such as GMSK vs. 8-PSK in EDGE and different MPR or RB configurations in WCDMA or LTE, separate maximum output power measurements are required to support the SAR test configurations and results – When power reduction is implemented, the maximum output power levels and triggering conditions for activating the power reduction and returning to normal full power conditions must be verified and reported according to published RF exposure KDB procedures or procedures determined through KDB inquiries

- The measured SAR results should be tabulated separately according to the test configurations documented in the test setup descriptions section of the test report, for the required test positions such as head, body-worn accessories, other use conditions (e.g. hotspot mode) and other host device specific exposure configurations
- Information relating to duty factors, TDMA time-slots and maximum output power of the various operating modes and conditions are also required to support the SAR results
- When SAR scaling is required to determine compliance for duty factors that are neither source-based nor inherent to the measurements, the scaling procedures and scaled results should be included after the tabulated SAR summary
- If the same scaling factor is applied to a group of SAR results; for example, a frequency band or operating mode, scaling the highest measured SAR within the group should generally be sufficient to demonstrate compliance
- The SAR scaling procedures required by the published RF exposure KDB procedures, specific KDB inquiries or other FCC requirements must be correctly applied to qualify for equipment approval
- When required, the SAR measurement variability and measurement uncertainty analysis results should be included after the tabulated SAR summary, according to procedures in KDB Publication 865664 D01. It should be clearly explained in the test report when SAR measurement uncertainty analysis is not required, but included for other purposes
- The analysis required to qualify for simultaneous transmission SAR test exclusion should be documented separately according to the head, body-worn accessory, other use conditions and host specific configurations described in the test setup section of the SAR report
- When applying SAR peak location separation ratio test exclusion, the peak location coordinates of each test configuration must be identified according to procedures in KDB Publication 447498 D01. The measured and estimated peak locations must be clearly identified, on SAR plots and illustrations as appropriate, to support the test exclusion
- The SAR distribution plots should be included in a separate attachment or appendix to the SAR report. The plots should be numbered sequentially and referenced in the tabulated SAR summary to facilitate review
- Information on test date, wireless mode, exposure configuration and test position, test channel & frequency, SAR probe serial number, probe conversion factors, transmission duty factor, tissue dielectric parameters, area and zoom scan measurement resolutions and dimensions, measurement drifts, 1-g or 10-g SAR and highest extrapolated SAR must be included on each SAR plot, with the peak location(s) clearly identified
- SAR plot is required for the highest measured SAR in each exposure configuration, wireless mode and frequency band combination; for example, WCDMA head SAR at 1900 MHz. Plots are also required when the measured SAR is > 1.5 W/kg, or > 7.0 W/kg for occupational exposure.
- The relevant boundaries of the test device should be correctly illustrated on SAR plots with peak SAR location(s) identified on the SAR distribution.
- Z-axis plots are generally optional; these are included to address certain specific concerns, as determined by the test laboratory and measurement results. When Z-axis plots are included, the results should be extrapolated to the phantom surface and the purpose of the plots must be clearly explained in the SAR report.
- The SAR numbers listed on the grant(s) of equipment authorization must be identified at the beginning of the SAR report, for each equipment class, according to procedures in KDB Publication 690783 D01. These reported SAR numbers should be highlighted in the SAR summary results for easy reference
- The SAR numbers listed on the grant(s) of equipment authorization must be identified at the beginning of the SAR report, for each equipment class, according to procedures in KDB Publication 690783 D01
- General specifications of the SAR system, SAR probe and dipole calibration certificates and results, tissue-equivalent media recipes, SAR system verification (dipole) plots, generic test setup photos and SAR system validation status information etc. should be included in a separate attachment or appendix to the SAR report

5 Product specific SAR Evaluation Procedures

5.1 SAR Evaluation for UMPC Mini-Tablets

SAR Evaluation for UMPC Mini-Tablets (FCC KDB 941225 D07)
– for certain small hand-held tablets and devices of similar form factors that are designed primarily for interactive hand-held use next to or near the body of users (devices are typically operated like a mini-tablet and are usually designed with certain UMPC features and operating characteristics) – test procedures are applicable to devices with a display and overall diagonal dimension ≤ 20 cm Larger devices – For larger tablets with a display or overall diagonal dimension > 20 cm, the SAR procedures in KDB Publication 616217 D04 are required Test distance 5 mm – A composite test separation distance of 5 mm is applied Test distance 10 mm – Depending on the device form factor, antenna locations, operating configurations and exposure conditions, a test separation distance up to 10 mm may be considered for some devices Under such circumstances, 10-g extremity SAR must also be measured at zero test separation for all measured 1-g (10 mm) SAR configurations to address hand exposure A KDB inquiry is required to determine 10 mm is acceptable for measuring 1-g SAR SAR testing – UMPC mini-tablet devices must be tested for 1-g SAR on all surfaces and side edges with a transmitting antenna located at ≤ 25 mm from that surface or edge, at 5 mm separation from a flat phantom, for the data modes, wireless technologies and frequency bands supported by the device to determine SAR compliance – When 1-g SAR is tested at 5 mm, 10-g SAR is not required Voice mode – When voice mode applies (speaker mode only) and the exposure conditions are not adequately covered by the data mode SAR results, additional SAR tests for voice mode may be required Next to ear – When next to the ear voice operations are supported, the handset and phablet procedures in KDB Publication 648474 D04 must be applied Hotspot mode – When the maximum output power levels of transmitters used in hotspot mode are not higher than those tested using UMPC minitablet procedures the more conservative UMPC mini-tablet SAR results can be used to support hotspot mode Simultaneous transmission – For simultaneous transmission conditions, the procedures described in KDB Publication 447498 D01 are used to determine 1-g SAR test exclusion and SAR test requirements Proximity sensing – Some UMPC mini-table devices may incorporated proximity sensing and power reduction mechanisms to address RF exposure and simultaneous transmission concerns. The proximity sensor triggering distance and coverage tests described in KDB Publication 616217 D04 for full size tablets should be applied to determine the non-reduced full power SAR test separation distance required for UMPC mini-tablets

5.2 SAR Evaluation for Handsets with Hotspot mode

SAR Evaluation for Handsets with Hotspot mode (FCC KDB 941225 D06)
– All applicable standalone and simultaneous transmission use conditions must be taken into consideration to determine SAR compliance – The head, body-worn accessory, next to body and hotspot mode SAR results are used to determine simultaneous transmission SAR test exclusion for these exposure conditions Near-body and hand-held use – SAR is measured for all edges and surfaces of the device with a transmitting antenna located within 25 mm from that surface or edge for the data modes, wireless technologies and frequency bands supporting hotspot mode – The SAR test separation distance for hotspot mode is determined according to device form factor When the overall length and width of a device is > 9 cm x 5 cm (~3.5" x 2") A test separation distance of 10 mm is required for hotspot mode SAR measurements Smaller devices A test separation distance of 5 mm or less is required – The combination of test distance and 1-g SAR measurements required for near-body exposure also supports hand-held exposure; therefore, separate 10-g extremity SAR evaluation is not necessary – The SAR results are used to determine simultaneous transmission SAR test exclusion for hotspot mode; otherwise, simultaneous transmission SAR measurement is required – For standalone battery-operated wireless router devices that require an external peripheral transmitter, such as an approved Wi-Fi or WWAN USB dongle or ExpressCard, to support hotspot mode: A reported SAR of 1.6 W/kg is used for the external transmitter to determine simultaneous transmission SAR test exclusion This excludes the use of sum of 1-g simultaneous transmission SAR test exclusion; the SAR to peak location separation ratio exclusion must be applied For USB dongles, the peak SAR location is assumed to be at 1 cm or less from the router surface, on the USB dongle For transmitter cards, SAR test exclusion is determined with peak SAR located at the edge of the router surface, centered along the plugin card slot If the built-in transmitter qualifies for SAR test exclusion; for example, a Wi-Fi module, the estimated SAR procedures in KDB Publication 447498 D01 is applied in conjunction with the 1.6 W/kg assumed for an external transmitter to determine SAR to peak location ratio SAR test exclusion Head and body-worn accessory – When the same wireless mode transmission configurations for voice and data are required for SAR measurements, the more conservative configuration with a smaller separation distance should be tested for the overlapping SAR configurations This typically applies to the back and front surfaces of a handset when SAR is required for both hotspot mode and body-worn accessory exposure conditions For devices with dimension > 9 cm x 5 cm the test separation distance used for hotspot mode SAR measurement is either 10 mm or that used in the body-worn accessory configuration, whichever is less For smaller devices with dimensions ≤ 9 cm x 5 cm a test separation of ≤ 5 mm must be used The combination of test distance and 1-g SAR measurements required for near-body exposure also supports hand-held exposure; therefore, separate 10-g extremity SAR evaluation is not necessary – When hotspot mode is enabled during voice calls, SAR compliance must be addressed for simultaneous voice and hotspot mode data in head (next to the ear) and body-worn accessory use conditions When separate transmitters are used, simultaneous transmission SAR for voice and hotspot mode data must be addressed

6 Technology specific SAR Evaluation Procedures

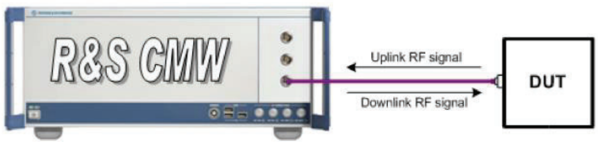
6.1 GSM

Evaluation Information
Frequency ranges and channel bandwidths: Each frequency band for devices operating in GSM/GPRS/EDGE modes Channel selection: The required test channels for each channel bandwidth and frequency band Per KDB 941225 D01; the channel selection criteria of KDB 447498 D01 must be applied otherwise, the low, mid, high channel should be used Antenna implementation: Antenna usage for the different operational modes and configurations are listed Voice and data mode: The applicability of voice and data modes for each rf-exposure configuration Power class: The power class of the radio implementation Nominal and maximum output power and tune-up tolerance: For modes with the same specified maximum output power and tolerance, the higher number time-slot configuration should be tested Conducted and radiated output power of wireless modes: On the required test channels (low, mid, high) the conducted output power levels are measured for all applicable modes

Evaluation Test Mode

Test mode setup:

Manufacturer tool based test mode



Modulation:

All modes (modulations and data rates) used by the EUT

Voice / Data - Mode

GSM voice mode → transmit with 1 time slot
GPRS and EDGE → may transmit up to 4 time slots
Class A device → Dual Transfer Mode defined by the multislot classes (see 3GPP TS 43.055 and TS 45.001)

Evaluation Steps
Rated highest maximum output power: 1. The highest rated conducted output power is listed for all relevant operational modes Conducted output power: 2. The actual conducted output power is measured in test mode on the required test channels (low, mid, high) and it is verified that the actual output power is within 2 dB of the highest rated output power 3. The duty cycle of the test mode is measured and recorded Test exclusion: 4. The test separation distance is determined with respect to the applicable device use cases

5. Using the highest rated maximum output power values a test exclusion is performed according to KDB 447498 D01 and RSS-102

Tissue Simulating Liquid and System Validation:

6. The tissue simulating liquid is checked and the system validation is performed directly before SAR testing

   Tissue simulating liquid and system validation is repeated every 48 h if needed

SAR Measurement:

7. SAR is measured using test mode for all test positions on the channel and operational mode combination with the highest actual output power
8. For modes with the same specified maximum output power and tolerance, the higher number time-slot configuration should be tested
8. The measured SAR values are scaled to the highest rated maximum output power value for the operational mode under test
9. The general test exclusion of KDB 447498 D01 is followed for the applicability of SAR testing to the other required test channels
10. When the 1g-SAR value is ≤ 0.8 W/kg it is not necessary to measure SAR for the other channels

SAR Repeatability:

10. If needed due to SAR results, repeated measurements are performed after all other SAR tests are finished

DUT Holder Perturbations:

11. If needed due to SAR results DUT holder perturbation verification is performed

6.2 MedRadio

Evaluation Information
Nominal and maximum output power and tune-up tolerance: The nominal and maximum conducted output power levels are given Conducted and radiated output power of wireless modes: On the required test channels (low, mid, high) the conducted output power levels are measured at the maximum achievable duty cycle Transmission duty factor: The duty factor is measured and reported as required per TCB workshop 2016-10

Evaluation Test Mode
Test mode setup: Manufacturer tool based test mode Modulation: All modes (modulations and data rates) used by the EUT Test packet interval: Maximum achievable duty factor

Evaluation Steps
Rated highest maximum output power: 1. The highest rated conducted output power is listed for all relevant operational modes Conducted output power: 2. The actual conducted output power is measured in test mode on the required test channels (low, mid, high) and it is verified that the actual output power is within 2 dB of the highest rated output power 3. The duty cycle of the test mode is measured and recorded Test exclusion: 4. The test separation distance is determined with respect to the applicable device use cases 5. Using the highest rated maximum output power values a test exclusion is performed according to KDB 447498 D01 and RSS-102 Tissue Simulating Liquid and System Validation: 6. The tissue simulating liquid is checked and the system validation is performed directly before SAR testing Tissue simulating liquid and system validation is repeated every 48 h if needed SAR Measurement: 7. SAR is measured using test mode for all test positions on the channel and operational mode combination with the highest actual output power 8. The measured SAR values are scaled to the highest rated maximum output power value for the operational mode under test 9. The general test exclusion of KDB 447498 D01 is followed for the applicability of SAR testing to the other required test channels SAR Repeatability: 10. If needed due to SAR results, repeated measurements are performed after all other SAR tests are finished DUT Holder Perturbations: 11. If needed due to SAR results DUT holder perturbation verification is performed

7 SAR Evaluation for Standalone Transmitter Operation

7.1 Radio Chipset/Module 1: GSM

7.1.1 Maximum specified output power

Maximum Specified Output Power incl. Tune-up Tolerance					
Band	Modulation	Antenna Port	Maximum Conducted Power [dBm]	Anntena Gain [dBi]	Maximum Radiated Power [dBm]
GSM 850	GPRS	GSM antenna	33.2	-2.4	30.8
GSM 850	EGPRS	GSM antenna	33.1	-2.4	30.7
PCS 1900	GPRS	GSM antenna	28.3	-2.9	25.4
PCS 1900	EGPRS	GSM antenna	28.3	-2.9	25.4

7.1.2 Conducted output power

Source-based time-averaged conducted Output Power - Antenna: - Band: GSM850								
Mode	Antenna port	Channel	Frequency [MHz]	Burst Power [dBm]	Frame Average Power [dBm]	Burst Tune-up Power [dBm]	Power Scaling Factor c_P	Duty Cycle [%]
GPRS 1 TX Slot	1	128	824.2	33.10	24.07	34.5	1.230	12.5
		188	836.2	33.00	23.97	34.5	1.259	12.5
		251	848.0	33.20	24.17	34.5	1.202	12.5
EGPRS 1 TX Slot	1	128	824.2	33.1	24.07	34.5	1.230	12.5
		188	836.2	33.0	23.97	34.5	1.259	12.5
		251	848.0	33.1	24.07	34.5	1.230	12.5

Notes	
1:	Conducted power is RMS average power
2:	Frame average power is calculated from conducted power by duty cycle correction: 1 Tx Slot = $10*\log_{10}(1/8)$ = -9.03 dB 2 Tx Slots = $10*\log_{10}(2/8)$ = -6.02 dB 3 Tx Slots = $10*\log_{10}(3/8)$ = -4.26 dB 4 Tx Slots = $10*\log_{10}(4/8)$ = -3.01 dB

Source-based time-averaged conducted Output Power - Antenna: - Band: PCS1900								
Mode	Antenna port	Channel	Frequency [MHz]	Burst Power [dBm]	Frame Average Power [dBm]	Burst Tune-up Power [dBm]	Power Scaling Factor c_P	Duty Cycle [%]
GPRS 1 TX Slot	1	512	1850.2	28.30	19.27	29.5	1.175	12.5
		661	1880	28.20	19.17	29.5	1.202	12.5
		810	1909.8	28.30	19.27	29.5	1.175	12.5
EGPRS 1 TX Slot	1	512	1850.2	28.30	19.27	29.5	1.175	12.5
		661	1880	28.20	19.17	29.5	1.202	12.5
		810	1909.8	28.30	19.27	29.5	1.175	12.5

Notes	
1:	Conducted power is RMS average power
2:	Frame average power is calculated from conducted power by duty cycle correction: 1 Tx Slot = $10*\log_{10}(1/8)$ = -9.03 dB 2 Tx Slots = $10*\log_{10}(2/8)$ = -6.02 dB 3 Tx Slots = $10*\log_{10}(3/8)$ = -4.26 dB 4 Tx Slots = $10*\log_{10}(4/8)$ = -3.01 dB

7.1.3 Product specific SAR evaluation requirements

UMPC mini-tablet devices (1-g) SAR					
Antenna	Test Position	Antenna to DUT Surface Separation [mm]	DUT to User Separation [mm]	SAR Required	Note
LTE antenna	Front	< 25	10	Yes	1
LTE antenna	Back	< 25	10	Yes	1
LTE antenna	Top	< 25	10	Yes	1
LTE antenna	Bottom	> 25	10	No	1
LTE antenna	Left	< 25	10	Yes	1
LTE antenna	Right	< 25	10	Yes	1

Notes
1: UMPC mini-tablet devices must be tested for 1-g SAR on all surfaces and side edges with a transmitting antenna located at ≤ 25 mm from that surface or edge, at 5 mm separation from a flat phantom; When 1-g SAR is tested at 5 mm, 10-g SAR is not required

7.1.4 General maximum output power based test exclusion per KDB 447498 D01

SAR Test Exclusion									
SAR Mode	Operating Band	Freqency [MHz]	Position	Tune-up Average Power [dBm]	Tune-up Average Power [mW]	Test Distance [mm]	Threshold Power [mW]	SAR Required	Note
Antenna: GSM antenna									
1-g	GSM850	848.0	Front	34.5	2818	10	33	Yes	1
1-g	GSM850	848.0	Back	34.5	2818	10	33	Yes	1
1-g	GSM850	848.0	Top	34.5	2818	10	33	Yes	1
1-g	GSM850	848.0	Bottom	34.5	2818	10	33	Yes	1
1-g	GSM850	848.0	Left	34.5	2818	10	33	Yes	1
1-g	GSM850	848.0	Right	34.5	2818	10	33	Yes	1
1-g	GSM1900	1909.8	Front	29.5	891	10	22	Yes	1
1-g	GSM1900	1909.8	Back	29.5	891	10	22	Yes	1
1-g	GSM1900	1909.8	Top	29.5	891	10	22	Yes	1
1-g	GSM1900	1909.8	Bottom	29.5	891	10	22	Yes	1
1-g	GSM1900	1909.8	Left	29.5	891	10	22	Yes	1
1-g	GSM1900	1909.8	Right	29.5	891	10	22	Yes	1

Notes
1: All surfaces and edges with a maximum power below the threshold power are excluded from SAR measurements; for all other surfaces or edges SAR measurements must be performed

7.1.5 General maximum output power based test exclusion per RSS-102

SAR Test Exclusion									
SAR Mode	Operating Band	Freqency [MHz]	Position	Tune-up Average Power [dBm]	Tune-up Average Power [mW]	Test Distance [mm]	Threshold Power [mW]	SAR Required	Note
Antenna: LTE antenna									
1-g	GSM850	848.0	Front	34.5	218.38	10	29.8	Yes	1
1-g	GSM850	848.0	Back	34.5	218.38	10	29.8	Yes	1
1-g	GSM850	848.0	Top	34.5	218.38	10	29.8	Yes	1
1-g	GSM850	848.0	Bottom	34.5	218.38	10	29.8	Yes	1
1-g	GSM850	848.0	Left	34.5	218.38	10	29.8	Yes	1
1-g	GSM850	848.0	Right	34.5	218.38	10	29.8	Yes	1
1-g	GSM1900	1909.8	Front	29.5	891.28	10	9.9	Yes	1
1-g	GSM1900	1909.8	Back	29.5	891.28	10	9.9	Yes	1
1-g	GSM1900	1909.8	Top	29.5	891.28	10	9.9	Yes	1
1-g	GSM1900	1909.8	Bottom	29.5	891.28	10	9.9	Yes	1
1-g	GSM1900	1909.8	Left	29.5	891.28	10	9.9	Yes	1
1-g	GSM1900	1909.8	Right	29.5	891.28	10	9.9	Yes	1

Notes
1: All surfaces and edges with a maximum power below the threshold power are excluded from SAR measurements; for all other surfaces or edges SAR measurements must be performed
2: Estimated SAR is calculated according to FCC KDB 447498 D01 from maximum conducted output power, operating frequency and test distance

7.1.6 Tissue simulating liquid validations

Tissue Validation									
Date	Tissue	Temp. [°C]	Freqency [MHz]	Liquid Parameter	Measured	Target	Delta [%]	Limit [%]	Note
2021-03-16	MSL-900	22.0	824.2	Relative Permittivity (ε_r)	54.636	55.242	-1.10	± 5	1
				Conductivity (σ)	0.951	0.969	-1.87	± 5	1
2021-03-16	MSL-900	22.0	836.2	Relative Permittivity (ε_r)	54.476	55.196	-1.30	± 5	1
				Conductivity (σ)	0.96	0.971	-1.18	± 5	1
2021-03-16	MSL-900	22.0	848.8	Relative Permittivity (ε_r)	54.434	55.158	-1.31	± 5	1
				Conductivity (σ)	0.975	0.987	-1.21	± 5	1
2021-03-16	MSL-900	22.0	900.0	Relative Permittivity (ε_r)	54.115	55.000	-1.61	± 5	1
				Conductivity (σ)	1.031	1.050	-1.81	± 5	1
2021-03-18	MSL-900	22.0	824.2	Relative Permittivity (ε_r)	54.591	55.242	-1.18	± 5	1
				Conductivity (σ)	0.951	0.969	-1.87	± 5	1
2021-03-18	MSL-900	22.0	836.2	Relative Permittivity (ε_r)	54.435	55.196	-1.38	± 5	1
				Conductivity (σ)	0.962	0.971	-0.98	± 5	1
2021-03-18	MSL-900	22.0	848.8	Relative Permittivity (ε_r)	54.338	55.158	-1.49	± 5	1
				Conductivity (σ)	0.974	0.987	-1.32	± 5	1
2021-03-18	MSL-900	22.0	900.0	Relative Permittivity (ε_r)	54.027	55.000	-1.77	± 5	1
				Conductivity (σ)	1.03	1.050	-1.90	± 5	1
2021-03-24	MSL-1900	21.0	1850.2	Relative Permittivity (ε_r)	52.352	53.300	-1.78	± 5	1
				Conductivity (σ)	1.506	1.520	-0.92	± 5	1
2021-03-24	MSL-1900	21.0	1880.0	Relative Permittivity (ε_r)	52.031	53.300	-2.38	± 5	1
				Conductivity (σ)	1.508	1.520	-0.79	± 5	1
2021-03-24	MSL-1900	21.0	1900.0	Relative Permittivity (ε_r)	52.017	53.300	-2.41	± 5	1
				Conductivity (σ)	1.492	1.520	-1.84	± 5	1
2021-03-24	MSL-1900	21.0	1909.8	Relative Permittivity (ε_r)	52.089	53.300	-2.27	± 5	1
				Conductivity (σ)	1.483	1.520	-2.43	± 5	1
2021-03-26	MSL-1900	22.0	1850.2	Relative Permittivity (ε_r)	52.728	53.300	-1.07	± 5	1
				Conductivity (σ)	1.528	1.520	0.53	± 5	1
2021-03-26	MSL-1900	22.0	1880.0	Relative Permittivity (ε_r)	52.53	53.300	-1.44	± 5	1
				Conductivity (σ)	1.559	1.520	2.57	± 5	1
2021-03-26	MSL-1900	22.0	1900.0	Relative Permittivity (ε_r)	52.374	53.300	-1.74	± 5	1
				Conductivity (σ)	1.579	1.520	3.88	± 5	1
2021-03-26	MSL-1900	22.0	1909.8	Relative Permittivity (ε_r)	52.257	53.300	-1.96	± 5	1
				Conductivity (σ)	1.584	1.520	4.21	± 5	1
2021-03-29	MSL-1900	21.0	1850.2	Relative Permittivity (ε_r)	52.511	53.300	-1.48	± 5	1
				Conductivity (σ)	1.563	1.520	2.83	± 5	1
2021-03-29	MSL-1900	21.0	1880.0	Relative Permittivity (ε_r)	52.148	53.300	-2.16	± 5	1
				Conductivity (σ)	1.577	1.520	3.75	± 5	1
2021-03-29	MSL-1900	21.0	1900.0	Relative Permittivity (ε_r)	52.04	53.300	-2.36	± 5	1
				Conductivity (σ)	1.568	1.520	3.16	± 5	1
2021-03-29	MSL-1900	21.0	1909.8	Relative Permittivity (ε_r)	52.059	53.300	-2.33	± 5	1
				Conductivity (σ)	1.563	1.520	2.83	± 5	1

Notes	
1:	Per KDB 865664 D01 the measured εr and σ of the tissue-equivalent medium used during probe calibration must be within 5% of the target parameters

7.1.7 System validations

System Validation													
Date	Dipole	Tissue	SAR	Freqency [MHz]	Power [mW]	Liquid Temp. [°C]	Power Drift [dB]	Measured SAR [W/kg]	Scaled 1W SAR [W/kg]	Target 1W SAR [W/kg]	Delta [%]	Limit [%]	Plot
2021-03-16	D900V2	MSL-900	1-g	900	250	22	0.03	2.8	11.2	11.1	0.9	± 10	1
2021-03-17	D900V2	MSL-900	1-g	900	250	22	0.02	2.75	11.00	11.1	-0.9	± 10	2
2021-03-18	D900V2	MSL-900	1-g	900	250	22	0.00	2.78	11.12	11.1	0.2	± 10	3
2021-03-24	D1900V2	MSL-1900	1-g	900	250	21	0.01	10.3	41.20	40.00	2.9	± 10	4
2021-03-25	D1900V2	MSL-1900	1-g	1900	250	22	-0.03	10.1	40.40	40.00	1.0	± 10	5
2021-03-26	D1900V2	MSL-1900	1-g	1900	250	22	-0.05	10.5	42.00	40.00	4.8	± 10	6
2021-03-29	D1900V2	MSL-1900	1-g	1900	250	21	-0.00	10.4	41.60	40.00	3.8	± 10	7
2021-03-30	D1900V2	MSL-1900	1-g	1900	250	22	-0.04	10.4	41.60	40.00	3.8	± 10	8

Notes	
1:	Per KDB 865664 D01 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
2:	Per KDB 865664 D02 section 2.3 j) only the SAR system verification plots, with the largest deviation from the dipole or qualified source SAR target are to be reported for each dipole or qualified source

7.1.8 SAR measurements

SAR Measurements - Band: GSM 850														
Date	Configuration			Position	Dist. [mm]	Power				SAR			Plot	Note
	Ant.	Mode	Exposure Config.			Ch.	Freq. [MHz]	Meas. Power [dBm]	Tune-up Power [dBm]	Power Drift [dB]	Meas. SAR [W/kg]	Scaled SAR [W/kg]		
2021-03-16	Liquid Temperature [°C] = 22.0													
2021-03-16	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Back	10	251	848.0	33.2	34.5	-0.19	0.615	0.830		
2021-03-16	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Right	10	251	848.0	33.2	34.5	-0.10	0.418	0.564		
2021-03-16	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Left	10	251	848.0	33.2	34.5	-0.01	0.263	0.355		
2021-03-16	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Top	10	251	848.0	33.2	34.5	-0.16	0.078	0.105		
2021-03-17	Liquid Temperature [°C] = 22.0													
2021-03-17	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Front	10	251	848.0	33.2	34.5	0.15	0.703	**0.948**	1	
2021-03-17	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Front	10	190	836.6	33.0	34.5	0.10	0.616	0.870		
2021-03-17	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Back	10	128	824.2	33.1	34.5	0.16	0.615	0.849		
2021-03-17	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Front	10	128	824.2	33.1	34.5	-0.16	0.569	0.785		
2021-03-17	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Top	10	128	824.2	33.1	34.5	-0.18	0.072	0.099		
2021-03-17	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Top	10	190	836.6	33.0	34.5	-0.12	0.075	0.106		
2021-03-18	Liquid Temperature [°C] = 22.0													
2021-03-18	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Back	10	190	836.6	33.0	34.5	-0.19	0.649	0.917		
2021-03-18	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Right	10	190	836.6	33.0	34.5	-0.12	0.377	0.533		
2021-03-18	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Left	10	190	836.6	33.0	34.5	-0.20	0.372	0.525		
2021-03-18	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Right	10	128	824.2	33.1	34.5	-0.06	0.391	0.540		
2021-03-18	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Left	10	128	824.2	33.1	34.5	0.07	0.367	0.507		

SAR Measurements - Band: PCS 1900														
Date	Configuration			Position	Dist. [mm]	Power				SAR			Plot	Note
	Ant.	Mode	Exposure Config.			Ch.	Freq. [MHz]	Meas. Power [dBm]	Tune-up Power [dBm]	Power Drift [dB]	Meas. SAR [W/kg]	Scaled SAR [W/kg]		
2021-03-24	Liquid Temperature [°C] = 21.0													
2021-03-24	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Front	10	512	1850.2	28.3	29.5	-0.06	0.780	1.028		
2021-03-24	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Right	10	512	1850.2	28.3	29.5	-0.15	0.569	0.750		
2021-03-24	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Left	10	512	1850.2	28.3	29.5	-0.06	0.217	0.286		
2021-03-24	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Top	10	512	1850.2	28.3	29.5	-0.03	0.083	0.109		
2021-03-25	Liquid Temperature [°C] = 22.0													
2021-03-25	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Back	10	512	1850.2	28.3	29.5	0.02	1.070	**1.411**	2	
2021-03-25	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Back	10	661	1880.0	28.2	29.5	-0.09	0.931	1.256		
2021-03-25	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Top	10	661	1880.0	28.2	29.5	-0.10	0.086	0.116		
2021-03-26	Liquid Temperature [°C] = 22.0													
2021-03-26	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Front	10	661	1880.0	28.2	29.5	-0.07	0.866	1.168		
2021-03-26	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Right	10	661	1880.0	28.2	29.5	0.03	0.618	0.834		
2021-03-26	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Front	10	810	1909.8	28.3	29.5	-0.15	0.819	1.080		
2021-03-26	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Right	10	810	1909.8	28.3	29.5	-0.16	0.581	0.766		
2021-03-29	Liquid Temperature [°C] = 21.0													
2021-03-29	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Left	10	661	1880.0	28.2	29.5	0.04	0.189	0.225		
2021-03-29	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Left	10	810	1909.8	28.3	29.5	0.19	0.147	0.194		

Notes	
1:	Measured SAR values are scaled to the maximum tune-up power specified for transmission mode
2:	The power drift must be ≤ ± 5 % or ≤ ± 0.2 dB

A:	Head (Next-to-ear)
B:	Generic device
C:	Body-worn
D:	Front-to-face
E:	Device with hinged or swivel antenna
F:	Body-supported
G:	Desktop device
H:	Clothing integrated device
I:	Limb-worn device
J:	Hand-held device

7.1.9 SAR repeatability

SAR Repeatability												
Date	Ant.	Exposure Configuration	Position	Mode	Dist. [mm]	Ch.	Freqency [MHz]	SAR [W/kg]		Largest to smallest Ratio	Plot	Note
								Original	Repeated			
2021-03-29	Liquid Temperature [°C] = 21.0											
2021-03-29	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Back	10	810	661	0.931	0.955	1.026	4	
2021-03-29	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Back	10	810	1909.8	0.950	0.838	1.134	6	
2021-03-29	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Back	10	512	1850.2	1.070	1.010	1.059	3	
2021-03-30	Liquid Temperature [°C] = 22.0											
2021-03-30	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Front	10	810	661	0.866	0.923	1.066	5	
2021-03-30	GSM	Test Mode A CS1 1 Timeslot Gamma 3	Body (1-g)	Front	10	810	1909.8	0.819	0.889	1.085	7	

Notes	
1:	Repeated measurement is not required when the original highest measured SAR is < 0.80 W/kg
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
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

7.1.10 DUT Holder Perturbations

DUT Holder Perturbations														
Date	Configuration			Position	Dist. [mm]	Channel		SAR					Plot	Note
	Ant.	Mode	Exposure Config.			Ch.	Freq. [MHz]	Original Reported [W/kg]	Original with holder [W/kg]	Repeated without holder [W/kg]	SAR Tolerance [%]	Corr. Reported SAR [W/kg]		
While all SAR measurements the DUT was placed on a foam bloc. No influence of the DUT holder is assumed. (Annex C)														

Notes	
1:	When the highest reported SAR of an antenna is > 1.2 W/kg (1-g) or 3.0 (10-g), holder perturbation verification is required for each antenna, using the highest SAR configuration among all applicable frequency bands
2:	If the SAR tolerance is negative which means that the SAR value without DUT holder is larger than the SAR value with DUT holder, the reported SAR value is corrected by the SAR tolerance in order to take the decrease in SAR value because of the DUT holder into account
3:	KDB inquiry is required if the highest reported SAR for each antenna, adjusted for increases in holder perturbation, would introduce noncompliance conditions or noticeably high differences due to perturbation