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Report On

Specific Absorption Rate Testing of the
DetNet CE4 Tagger

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IC: 24476-16541610

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Document 75943624 Report 08 Issue 2 **February 2019**

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REPORT ON	Specific Absorption Rate Testing of the DetNet CE4 Tagger Document 75943624 Report 08 Issue 2 February 2019
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DATED	04 February 2019

This report has been up-issued to Issue 2 to amend the FCC and IC ID's

CONTENTS

SECTION 1

REPORT SUMMARY

Specific Absorption Rate Testing of the
DetNet CE4 Tagger

Product Service

1.1 INTRODUCTION

The information contained in this report is intended to show verification of the Specific Absorption Rate Testing of the DetNet CE4 Tagger to the requirements of KDB 447498 D01 v06 General RF Exposure Guidance.

Objective	To perform Specific Absorption Rate Testing to determine the Equipment Under Test's (EUT's) compliance with the requirements specified of KDB 447498 D01 v06 General RF Exposure Guidance, for the series of tests carried out.
Applicant	DetNet South Africa (Pty) Ltd
Manufacturer	DetNet South Africa (Pty) Ltd
Manufacturing Description	Hand held electronic tester for use with electronic detonators in the mining and blasting industry.
Model Number	CE4 Tagger v4
Declared Variant	CE4 Tagger v3
Serial/IMEI Number(s)	Not Serialised (75943624-TSR0005)
Number of Samples Tested	1
Hardware Version	V4
Software Version	36230B
Battery Cell Manufacturer	EEMB
Battery Model Number	LP605590-PCM-NTC-LD
Test Specification/Issue/Date	KDB 447498 D01 v06 General RF Exposure Guidance
Start of Test	19 September 2018
Finish of Test	19 September 2018
Related Document(s)	FCC 47 CFR 2.1093: 2017 KDB 865664 – D01 v01r04 KDB 865664 – D02 v01r02 KDB 248227 – D01 v02r02 IEEE 1528 - 2013 RSS - 102 Issue 5 - March 2015
Name of Engineer(s)	Stephen Dodd

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1.2 BRIEF SUMMARY OF RESULTS

The measurements shown in this report were made in accordance with the procedures specified KDB 447498 D01 v06 General RF Exposure Guidance.

The maximum 1 g volume averaged stand-alone SAR found during this Assessment:

Max 1 g SAR (W/kg) Body	0.003 (Measured)	**0.02** (Scaled)
The maximum 1 g volume averaged SAR level measured for all the tests performed did not exceed the limits for General Population/Uncontrolled Exposure (W/kg) Partial Body of 1.6 W/kg.		

The maximum 1 g volume averaged stand-alone Reported SAR found during this Assessment for each supported mode:

Band	Test Configuration	Max Reported Scaled SAR (W/kg)	Highest Simultaneous Transmission Scaled SAR (W/kg)
2.4 GHz WLAN	Body	0.02	**0.03**
13.56 MHz NFC	Body	0.01 (Estimated)	
The maximum 1 g volume averaged SAR level measured for all the tests performed (including simultaneous transmission analysis results) did not exceed the limits for General Population/Uncontrolled Exposure (W/kg) Partial Body of 1.6 W/kg.			

Product Service

1.3 TEST RESULTS SUMMARY

1.3.1 System Performance / Validation Check Results

Prior to formal testing being performed a System Check was performed in accordance with KDB 865664 and the results were compared against published data in Standard IEEE 1528-2013. The following results were obtained: -

System performance / Validation results

Date	Frequency (MHz)	Max 1 g SAR (W/kg)*	Percentage Drift on Reference
19/09/2018	2450	50.56	-1.25

*Normalised to a forward power of 1W

1.3.2 Results Summary Tables

WLAN 2450 MHz - 802.11b 20MHz 11 Mbps - Body Specific Absorbtion Rate (Maximum SAR) 1 g Results

Test Position	Channel Number	Frequency (MHz)	SAR Scan Type	Measured Average Power (dBm)	Tune Up (dBm)	Measured 1 g SAR (W/kg)	Scaled 1 g SAR (W/kg)	Duty Factor Scaled 1 g SAR (W/kg)	Scan Figure Number
0 mm Front Face	1	2412	Fast	16.88	18.00	0.002	0.003	0.01	2
0 mm Rear Face	1	2412	Fast	16.88	18.00	0.003	0.004	0.02	3
0 mm Left Edge	1	2412	Fast	16.88	18.00	0.005	0.006	0.03	4
0 mm Left Edge	1	2412	Full	16.88	18.00	0.003	0.004	**0.02**	5
Limit for General Population (Uncontrolled Exposure) 1.6 W/kg (1 g) KDB 248227 D01 v02 – A duty factor scaling was applied to the scaled SAR as per section 2.2 KDB 248227 D01 v02 – Fast SAR was used to determine the initial test position as per Section 5.1.1 KDB 248227 D01 v02 – When the *reported* SAR of the highest measured maximum output power channel for the exposure configuration is ≤ 0.8 W/kg, no further SAR testing is required for 802.11b DSSS in that exposure configuration as per Section 5.2.1 KDB 248227 D01 v02 - Testing was not required for OFDM as per Section 5.2.2									

Product Service

1.3.3 Simultaneous Transmission

Position	WLAN 2.4 GHz 1 g SAR (W/kg) (Scaled SAR values)	NFC - 13.56 MHz 1 g SAR (W/kg) (Estimated SAR values)	∑ 1 g SAR (W/kg)
Front Face	0.01 (Fast)	0.01	0.02
Rear Face	0.02 (Fast)	0.01	0.03
Left Face	0.03 (Fast)	0.01	0.04
Left Face	0.02 (Full)	0.01	**0.03**
Simultaneous Transmission KDB 447498 D01			

<u>SAR estimation KDB 447498 D01 Section 4.3.2b</u>

When an antenna qualifies for the standalone SAR test exclusion of 4.3.1 and also transmits simultaneously with other antennas, the standalone SAR value must be estimated according to the following to determine the simultaneous transmission SAR test exclusion criteria:

[(*max. power of channel, including tune-up tolerance, mW*) / (*min. test separation distance, mm*)]·[√f(GHz)/*x*] W/kg, for *test separation distances* ≤ 50 mm;
where *x* = 7.5 for 1-g SAR and *x* = 18.75 for 10-g SAR.

Therefore the estimated SAR for NFC =

[(*3.98 mW*) / (*5 mm*)]·[√0.01356 GHz/*7.5*] = 0.01 W/kg for 1 g SAR

1.3.4 Standalone SAR Test Exclusion Considerations (KDB 447498 D01

The 1 g SAR Test exclusion thresholds for 100 MHz to 6 GHz *test separation distances* ≤ 50 mm are determined by:

[(*max power of channel, including tune-up tolerance, mW) / (min. test separation distance, mm)] [√f (GHz)]* ≤ 3.0, where

- f (GHz) is the RF channel transmit frequency in GHz.
- Power and distance are rounded to the nearest mW and mm before calculation.
- The result is rounded to one decimal place for comparison.
- When the maximum test separation distance is < 5 mm, a distance of 5 mm is applied.

RAT & Band	Frequency (MHz)	Power (dBm)	Power (mW)	Test Position	Distance (mm)	Threshold	Test Exclusion
WLAN 2450 MHz	2412	18.00	63.10	Body	<5	19.6	No
WLAN 2450 MHz	2432	18.00	63.10	Body	<5	19.6	No
WLAN 2450 MHz	2437	18.00	63.10	Body	<5	19.7	No
WLAN 2450 MHz	2457	18.00	63.10	Body	<5	19.7	No

Note: The EUT also supports NFC at 13.56 MHz. As SAR measurement procedures are not established for frequencies below 100 MHz, SAR test exclusion was applied.

1.3.5 Technical Description

The equipment under test (EUT) was a DetNet CE4 Tagger. A full technical description can be found in the manufacturer's documentation.

1.3.6 Test Configuration and Modes of Operation

The testing was performed with an Integral 3.7 Volt Lithium-ion battery supplied by DetNet South Africa (Pty) Ltd and manufactured by EEMB.

The product is a Hand held electronic tester for use with electronic detonators in the mining and blasting industry.

Both product variants (CE4 Tagger v3 / CE4 Tagger v4) contain a Gainspain GS1011MEP pre-approved 2.4 GHz WLAN module which is FCC and Industry Canada certified (FCC ID: YOPGS101MEP and IC: 9154AGS1011MEP). The modules are located in the main unit of the EUT.

CE4 Tagger v4 also incorporates NFC while the CE4 Tagger v3 does not. Estimated SAR was used for NFC to cover simultaneous transmission assessment of the CE4 Tagger v4.

The EUT Firmware limits the device to 802.11b 20 MHz at 11 Mbps for the 2.4 GHz frequency band. Testing was achieved using the EUT's internal software and settings supplied by the customer. For each scan the EUT was configured into a continuous transmission test mode by a DetNet Engineer.

All channels tested had a Duty Cycle of 20 %, therefore duty cycle scaling was applied to the scaled SAR results as per section 2.2 of KDB 248227.

All surfaces of the EUT that are within 25 mm of the Wifi Antenna were assessed for SAR at a 0 mm separation distance from the phantom.

All testing was performed against an Elliptical Flat Phantom. The Elliptical Phantom dimensions are 600 mm major axis and 400 mm minor axis with a shell thickness of 2.00mm. The phantom was filled to a minimum depth of 150 mm with the appropriate simulant liquid. The dielectric properties were in accordance with the requirements specified in KDB 865665.

Included in this report are descriptions of the test method; the equipment used and an analysis of the test uncertainties applicable and diagrams indicating the locations of maximum SAR for each test position.

1.4 FCC POWER MEASUREMENTS

1.4.1 Method

Conducted power measurements were made using a power meter.

1.4.2 Conducted Power Measurements

WLAN 2450 MHz

Mode	Frequency (MHz)	Duty Cycle (%)	Burst Average Power (dBm)	Tune Up Value (dBm)
802.11b - 20 MHz – 11 Mbps	2412	20.00	**16.88**	18.00
802.11b - 20 MHz – 11 Mbps	2432	20.00	16.54	18.00
802.11b - 20 MHz – 11 Mbps	2437	20.00	16.51	18.00
802.11b - 20 MHz – 11 Mbps	2457	20.00	16.33	18.00

SECTION 2

TEST DETAILS

Specific Absorption Rate Testing of the
DetNet CE4 Tagger

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2.1 DASY5 MEASUREMENT SYSTEM

2.1.1 System Description

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

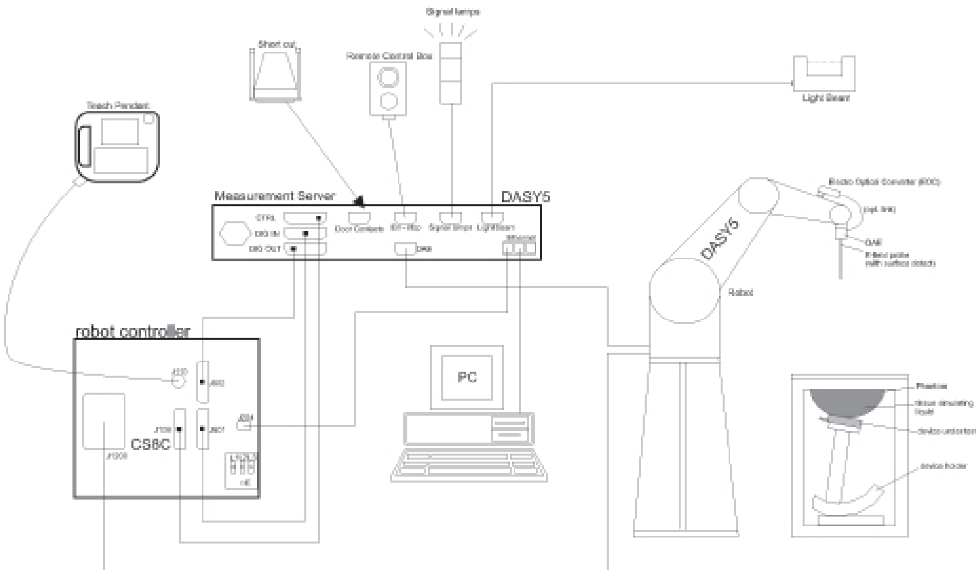

Figure 1 System Description Diagram

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 Win8.1 professional 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.

2.1.2 Probe Specification

The probes used by the DASY system are isotropic E-field probes, constructed with a symmetric design and a triangular core. The probes have built-in shielding against static charges and are contained within a PEEK enclosure material. These probes are specially designed and calibrated for use in liquids with high permittivities. The frequency range of the probes are from 6 MHz to
6 GHz.

2.1.3 Data Acquisition Electronics

The data acquisition electronics (DAE4 or DAE3) consist of a highly sensitive electrometer-grade preamplifier with auto-zeroing, a channel and gain-switching multiplexer, a fast 16 bit AD-converter and a command decoder with a 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 both the DAE4 as well as of the DAE3 box is 200MOhm; the inputs are symmetrical and floating. Common mode rejection is above 80 dB.

2.1.4 SAR Evaluation Description

The DASY5 software includes all numerical procedures necessary to evaluate the spatial peak SAR values.

Based on the IEEE 1528 standard, a new algorithm has been implemented. The spatial-peak SAR can be computed over any required mass.

The base for the evaluation is a "cube" measurement in a volume of 30 mm^3 (7x7x7 points). The measured volume must include the 1 g and 10 g cubes with the highest averaged SAR values. For that purpose, the centre of the measured volume is aligned to the interpolated peak SAR value of a previously performed area scan. If the 10 g cube or both cubes are not entirely inside the measured volumes, the system issues a warning regarding the evaluated spatial peak values within the Post processing engine (SEMCAD X). This means that if the measured volume is shifted, higher values might be possible. To get the correct values you can use a finer measurement grid for the area scan. In complicated field distributions, a large grid spacing for the area scan might miss some details and give an incorrectly interpolated peak location.

The entire evaluation of the spatial peak values is performed within the Post-processing engine (SEMCAD X). The system always gives the maximum values for the 1 g and 10 g cubes. The algorithm to find the cube with highest averaged SAR is divided into the following stages:

1. extraction of the measured data (grid and values) from the Zoom Scan
2. calculation of the SAR value at every measurement point based on all stored data (A/D values and measurement parameters)
3. generation of a high-resolution mesh within the measured volume
4. interpolation of all measured values from the measurement grid to the high-resolution grid
5. extrapolation of the entire 3-D field distribution to the phantom surface over the distance from sensor to surface
6. calculation of the averaged SAR within masses of 1 g and 10 g

2.1.5 Interpolation, Extrapolation and Detection of Maxima

The probe is calibrated at the centre of the dipole sensors which is located 1 to 2.7 mm away from the probe tip. During measurements, the probe stops shortly above the phantom surface, depending on the probe and the surface detecting system. Both distances are included as parameters in the probe configuration file. The software always knows exactly how far away the measured point is from the surface. As the probe cannot directly measure at the surface, the values between the deepest measured point and the surface must be extrapolated.

In DASY5, the choice of the coordinate system defining the location of the measurement points has no influence on the uncertainty of the interpolation, Maxima Search and extrapolation routines. The interpolation, extrapolation and maximum search routines are all based on the modified Quadratic Shepard's method. Thereby, the interpolation scheme combines a least-square fitted function method and a weighted average method which are the two basic types of computational interpolation and approximation. The DASY5 routines construct a once-continuously differentiable function that interpolates the measurement values as follows:

For each measurement point a trivariate (3-D) / bivariate (2-D) quadratic is computed.
It interpolates the measurement values at the data point and forms a least-square fit to neighbouring measurement values. The spatial location of the quadratic with respect to the measurement values is attenuated by an inverse distance weighting. This is performed since the calculated quadratic will fit measurement values at nearby points more accurate than at points located further away.

After the quadratics are calculated for at all measurement points, the interpolating function is calculated as a weighted average of the quadratics.

There are two control parameters that govern the behaviour of the interpolation method. One specifies the number of measurement points to be used in computing the least-square fits for the local quadratics. These measurement points are the ones nearest the input point for which the quadratic is being computed. The second parameter specifies the number of measurement points that will be used in calculating the weights for the quadratics to produce the final function. The input data points used there are the ones nearest the point at which the interpolation is desired. Appropriate defaults are chosen for each of the control parameters

The trivariate quadratics that have been previously computed for the 3-D interpolation and whose input data are at the closest distance from the phantom surface, are used in order to extrapolate the fields to the surface of the phantom.

In order to determine all the field maxima in 2-D (Area Scan) and 3-D (Zoom Scan), the measurement grid is refined by a default factor of 10 and the interpolation function is used to evaluate all field values between corresponding measurement points. Subsequently, a linear search is applied to find all the candidate maxima. In a last step, non-physical maxima are removed and only those maxima which are within 2 dB of the global maximum value are retained.

In the Area Scan, the gradient of the interpolation function is evaluated to find all the extrema of the SAR distribution. The uncertainty on the locations of the extrema is less than 1/20 of the grid size. Only local maxima within 2 dB of the global maximum are searched and passed for the Zoom Scan measurement.

In the Zoom Scan, the interpolation function is used to extrapolate the Peak SAR from the lowest measurement points to the inner phantom surface (the extrapolation distance). The uncertainty increases with the extrapolation distance. To keep the uncertainty within 1 % for the 1 g and 10 g cubes, the extrapolation distance should not be larger than 5 mm.

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2.1.6 Averaging and Determination of Spatial Peak SAR

The interpolated data is used to average the SAR over the 1 g and 10 g cubes by spatially discretising the entire measured volume. The resolution of this spatial grid used to calculate the averaged SAR is 1 mm or about 42875 interpolated points. The resulting volumes are defined as cubical volumes containing the appropriate tissue parameters that are cantered at the location. The location is defined as the centre of the incremental volume (voxel).

The spatial-peak SAR must be evaluated in cubical volumes containing a mass that is within 5 % of the required mass. The cubical volume centred at each location, as defined above, should be expanded in all directions until the desired value for the mass is reached, with no surface boundaries of the averaging volume extending beyond the outermost surface of the considered region. In addition, the cubical volume should not consist of more than 10 % of air. If these conditions are not satisfied, then the centre of the averaging volume is moved to the next location. Otherwise, the exact size of the final sampling cube is found using an inverse polynomial approximation algorithm, leading to results with improved accuracy. If one boundary of the averaging volume reaches the boundary of the measured volume during its expansion, it will not be evaluated at all. Reference is kept of all locations used and those not used for averaging the SAR. All average SAR values are finally assigned to the centred location in each valid averaging volume.

All locations included in an averaging volume are marked to indicate that they have been used at least once. If a location has been marked as used but has never been assigned to the centre of a cube, the highest averaged SAR value of all other cubical volumes which have used this location for averaging is assigned to this location. Only those locations that are not part of any valid averaging volume should be marked as unused. For the case of an unused location, a new averaging volume must be constructed which will have the unused location centred at one surface of the cube. The remaining five surfaces are expanded evenly in all directions until the required mass is enclosed, regardless of the amount of included air. Of the six possible cubes with one surface centred on the unused location, the smallest cube is used, which still contains the required mass.

If the final cube containing the highest averaged SAR touches the surface of the measured volume, an appropriate warning is issued within the Post-processing engine.

2.2 WLAN 2450 MHz - 802.11b 20 MHz 11 Mbps - BODY SAR TEST RESULTS

SOFTWARE VERSION:	52.10.1(1476)	**AMBIENT TEMPERATURE:**	23.4 °C
DATE:	19/09/2018	**RELATIVE HUMIDITY:**	62.3 %
PHANTOM:	QD OVA 004 Ax	**CONDUCTIVITY:**	1.995 S/m
DUT CONFIGURATION:	802.11b 20 MHz 11 Mbps	**RELATIVE PERMITTIVITY:**	53.020 ε_r
DUT POSITION:	0 mm – Front Face	**LIQUID TEMPERATURE:**	20.9 °C
RAT:	WLAN	**SCAN TYPE:**	Fast
FREQUENCY:	2412 MHz	**DRIFT:**	0.77 dB
MODULATION:	DSSS	**PEAK SAR:**	<0.01 W/kg
DUTY CYCLE:	20.0 % (scaled to 100 %)	**SAR (1g) - REPORTED:**	0.01 W/kg

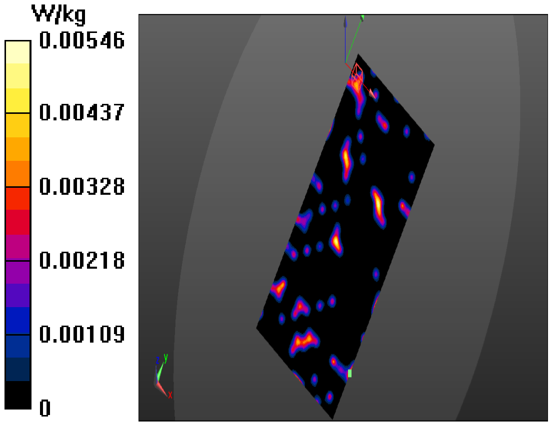

Figure 2: SAR Body Testing Results for the CE4 Tagger at 2412 MHz

SOFTWARE VERSION:	52.10.1(1476)	**AMBIENT TEMPERATURE:**	23.4 °C
DATE:	19/09/2018	**RELATIVE HUMIDITY:**	62.3 %
PHANTOM:	QD OVA 004 Ax	**CONDUCTIVITY:**	1.995 S/m
DUT CONFIGURATION:	802.11b 20 MHz 11 Mbps	**RELATIVE PERMITTIVITY:**	53.020 ε_r
DUT POSITION:	0 mm – Rear Face	**LIQUID TEMPERATURE:**	20.9 °C
RAT:	WLAN	**SCAN TYPE:**	Fast
FREQUENCY:	2412 MHz	**DRIFT:**	0.14 dB
MODULATION:	DSSS	**PEAK SAR:**	<0.01 W/kg
DUTY CYCLE:	20.0 % (scaled to 100 %)	**SAR (1g) - REPORTED:**	0.02 W/kg

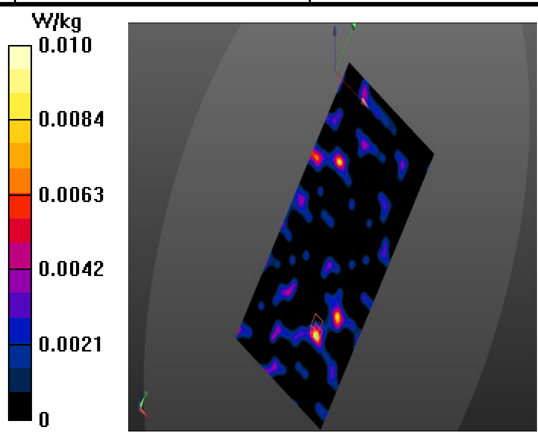

Figure 3: SAR Body Testing Results for the CE4 Tagger at 2412 MHz

Product Service

SOFTWARE VERSION:	52.10.1(1476)	**AMBIENT TEMPERATURE:**	23.4 °C
DATE:	19/09/2018	**RELATIVE HUMIDITY:**	62.3 %
PHANTOM:	QD OVA 004 Ax	**CONDUCTIVITY:**	1.995 S/m
DUT CONFIGURATION:	802.11b 20 MHz 11 Mbps	**RELATIVE PERMITTIVITY:**	53.020 ε_r
DUT POSITION:	0 mm – Left Edge	**LIQUID TEMPERATURE:**	20.9 °C
RAT:	WLAN	**SCAN TYPE:**	Fast
FREQUENCY:	2412 MHz	**DRIFT:**	1.16 dB
MODULATION:	DSSS	**PEAK SAR:**	<0.01 W/kg
DUTY CYCLE:	20.0 % (scaled to 100 %)	**SAR (1g) - REPORTED:**	0.03 W/kg

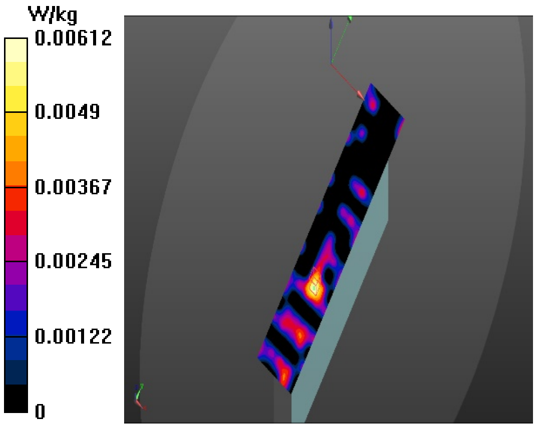

Figure 4: SAR Body Testing Results for the CE4 Tagger at 2412 MHz

SOFTWARE VERSION:	52.10.1(1476)	**AMBIENT TEMPERATURE:**	23.4 °C
DATE:	19/09/2018	**RELATIVE HUMIDITY:**	62.3 %
PHANTOM:	QD OVA 004 Ax	**CONDUCTIVITY:**	1.995 S/m
DUT CONFIGURATION:	802.11b 20 MHz 11 Mbps	**RELATIVE PERMITTIVITY:**	53.020 ε_r
DUT POSITION:	0 mm – Left Edge	**LIQUID TEMPERATURE:**	20.9 °C
RAT:	WLAN	**SCAN TYPE:**	Full
FREQUENCY:	2412 MHz	**DRIFT:**	-0.98 dB
MODULATION:	DSSS	**PEAK SAR:**	<0.01 W/kg
DUTY CYCLE:	20.0 % (scaled to 100 %)	**SAR (1g) - REPORTED:**	0.02 W/kg

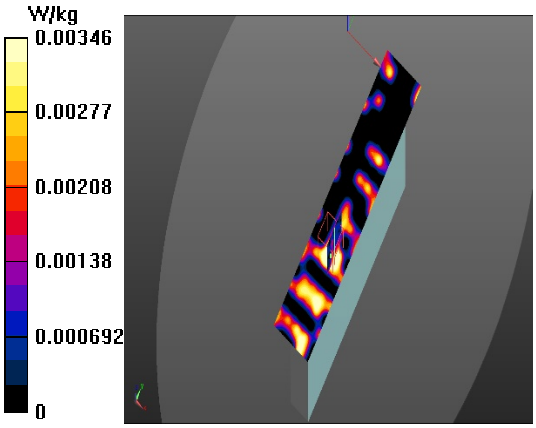

Figure 5: SAR Body Testing Results for the CE4 Tagger at 2412 MHz

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SECTION 3

TEST EQUIPMENT USED

3.1 TEST EQUIPMENT USED

The following test equipment was used at TÜV SÜD Product Service:

Instrument Description	Manufacturer	Model Type	TE Number	Cal Period (months)	Calibration Due Date
10MHz - 2.5GHz, Amplifier	IndexSar Ltd	VBM2500-3	0051	-	O/P Mon
Power Sensor	Rohde & Schwarz	NRV-Z1	0178	12	08-Jun-2019
Power Sensor	Rohde & Schwarz	NRV- Z1	3563	12	08-Jun-2019
P-Series Power Meter	Agilent Technologies	N1911A	3981	12	29-Sep-2018
Power Sensor	Agilent Technologies	N1921A	3983	12	29-Sep-2018
Signal Generator	Hewlett Packard	ESG4000A	61	12	20-Jul-2019
Attenuator (20dB, 10W)	Weinschel	37-20-34	482	12	01-Nov-2018
Bi-directional Coupler	IndexSar Ltd	7401 (VDC0830-20)	2414	-	O/P Mon
Thermometer	Digitron	T208	64	12	23-May-2019
K Type Thermocouple	Unknown	TYPE K	65	12	23-May-2019
Hygrometer	Rotronic	I-1000	2784	12	09-Apr-2019
Dual Channel Power Meter	Rohde & Schwarz	NRVD	2979	12	08-Jun-2019
Data Acquisition Electronics	Speag	DAE 4 - SD 000 D04 BM	4689	12	15-Dec-2018
Measurement Server	Speag	DASY 5 Measurement Server	4692	-	TU
Elliptical Phantom	Speag	ELI Phantom	4833	-	TU
Dosimetric SAR Probe	Speag	EX3DV4	4700	12	15-Dec-2018
Mounting Platform for TX90XL Robot and Phantoms	Speag	MP6C-TX90XL Mounting Platform Extended	4702	-	TU
Robot	Speag	TX90 XLspeag Robot	4704	-	TU
EUT Holder	Speag	N/A	3870	-	TU
MBBL Fluid	Speag	Batch 2	N/A	Weekly	24-Sep-2018
2450 MHz Dipole	Speag	D2450V2	3875	12	8-Dec-2018

TU - Traceability Unscheduled
O/P Mon – Output Monitored using calibrated equipment

3.2 TEST SOFTWARE

The following software was used to control the TÜV SÜD Product Service DASY System.

Instrument	Version Number
DASY system	52.10.1(1476)

3.3 DIELECTRIC PROPERTIES OF SIMULANT LIQUIDS

The fluid properties of the simulant fluids used during routine SAR evaluation meet the dielectric properties required KDB 865665.

The dielectric properties of the tissue simulant liquids used for the SAR testing at TÜV SÜD Product Service are as follows:-

Fluid Type and Frequency	Relative Permittivity Target	Relative Permittivity Measured	Conductivity Target	Conductivity Measured
2450 MHz MBBL	52.70	52.96	1.95	2.03

3.4 TEST CONDITIONS

3.4.1 Test Laboratory Conditions

Ambient temperature: Within +15°C to +35°C.
The actual temperature during the testing ranged from 23.4 °C to 23.4 °C.
The actual humidity during the testing ranged from 62.3 % to 62.3 % RH.

3.4.2 Test Fluid Temperature Range

Frequency	Fluid	Min Temperature °C	Max Temperature °C
2450 MHz	MBBL	20.9	20.9

3.4.3 SAR Drift

The maximum SAR Drift was recorded as 1.16 dB

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3.5 MEASUREMENT UNCERTAINTY

Body, Fast SAR Measurements, 300 MHz to 3 GHz Using Probe EX3DV4 - SN3759

Source of Uncertainty	Uncertainty ± %	Probability distribution	Div	c_i (10 g)	Standard Uncertainty ± % (10 g)	v_i (v_{eff})
Measurement System						
Probe calibration	6.0	N	1.00	0.00	0.0	
Axial Isotropy	4.7	R	1.73	0.70	1.9	Infinity
Hemispherical Isotropy	9.6	R	1.73	0.70	3.9	Infinity
Boundary effect	1.0	R	1.73	1.00	0.6	Infinity
Linearity	4.7	R	1.73	1.00	2.7	Infinity
System Detection limits	1.0	R	1.73	1.00	0.6	Infinity
Modulation response	2.4	R	1.73	1.00	1.4	Infinity
Readout electronics	0.3	N	1.00	0.00	0.0	
Response time	0.8	R	1.73	0.00	0.0	
Integration time	2.6	R	1.73	1.00	1.5	Infinity
RF ambient noise	3.0	R	1.73	1.00	1.7	Infinity
RF ambient reflections	3.0	R	1.73	0.00	0.0	
Probe positioner	0.4	R	1.73	1.00	0.2	Infinity
Probe positioning	2.9	R	1.73	1.00	1.7	Infinity
Spatial x-y-Resolution	10.0	R	1.73	1.00	5.8	Infinity
Fast SAR z-Approximation	7.0	R	1.73	1.00	4.0	Infinity
Test sample related						
Device Positioning	2.9	N	1.00	1.00	2.9	145
Device Holder	3.6	N	1.00	1.00	3.6	5
Input Power and SAR Drift	5.0	R	1.73	1.00	0.2	Infinity
Phantom and Setup						
Phantom uncertainty	6.1	R	1.73	1.00	3.5	Infinity
SAR Correction	1.9	R	1.73	0.00	0.0	
Liquid conductivity Meas.	2.5	R	1.73	0.00	0.0	
Liquid Permittivity Meas.	2.5	R	1.73	0.00	0.0	
Temp. Unc. Conductivity	3.4	R	1.73	0.00	0.0	
Temp. Unc. Permittivity	0.4	R	1.73	0.00	0.0	
Combined Standard Uncertainty		**RSS**			11.0	
Expanded Standard Uncertainty		**K=2**			21.9	

Body, Full SAR Measurements, 300 MHz to 3 GHz Using Probe EX3DV4 - SN3759

Source of Uncertainty	Uncertainty ± %	Probability distribution	Div	c_i (10 g)	Standard Uncertainty ± % (10 g)	v_i (v_{eff})
Measurement System						
Probe calibration	6.0	N	1.00	1.00	6.0	Infinity
Axial Isotropy	4.7	R	1.73	0.70	1.9	Infinity
Hemispherical Isotropy	9.6	R	1.73	0.70	3.9	Infinity
Boundary effect	1.0	R	1.73	1.00	0.6	Infinity
Linearity	4.7	R	1.73	1.00	2.7	Infinity
System Detection limits	1.0	R	1.73	1.00	0.6	Infinity
Modulation response	2.4	R	1.73	1.00	1.4	Infinity
Readout electronics	0.3	N	1.00	1.00	0.3	Infinity
Response time	0.8	R	1.73	1.00	0.5	Infinity
Integration time	2.6	R	1.73	1.00	1.5	Infinity
RF ambient noise	3.0	R	1.73	1.00	1.7	Infinity
RF ambient reflections	3.0	R	1.73	1.00	1.7	Infinity
Probe positioner	0.4	R	1.73	1.00	0.2	Infinity
Probe positioning	2.9	R	1.73	1.00	1.7	Infinity
Max SAR Evaluation	2.0	R	1.73	1.00	1.2	Infinity
Test sample related						
Device Positioning	2.9	N	1.00	1.00	2.9	145
Device Holder	3.6	N	1.00	1.00	3.6	5
Input Power and SAR Drift	5.0	R	1.73	1.00	0.2	Infinity
Phantom and Setup						
Phantom uncertainty	6.1	R	1.73	1.00	3.5	Infinity
SAR Correction	1.9	R	1.73	0.84	0.9	Infinity
Liquid conductivity Meas.	2.5	R	1.73	0.71	1.0	Infinity
Liquid Permittivity Meas.	2.5	R	1.73	0.26	0.4	Infinity
Temp. Unc. Conductivity	3.4	R	1.73	0.71	1.4	Infinity
Temp. Unc. Permittivity	0.4	R	1.73	0.26	0.1	Infinity
Combined Standard Uncertainty		**RSS**			10.7	361
Expanded Standard Uncertainty		**K=2**			21.5	

SECTION 4

ACCREDITATION, DISCLAIMERS AND COPYRIGHT

4.1 ACCREDITATION, DISCLAIMERS AND COPYRIGHT

This report relates only to the actual item/items tested.

Our UKAS Accreditation does not cover opinions and interpretations and any expressed are outside the scope of our UKAS Accreditation.

Results of tests not covered by our UKAS Accreditation Schedule are marked NUA (Not UKAS Accredited).

Product Service

ANNEX A

PROBE CALIBRATION REPORT

Product Service

Calibration Laboratory of
Schmid & Partner
Engineering AG
Zeughausstrasse 43, 8004 Zurich, Switzerland

S Schweizerischer Kalibrierdienst
C Service suisse d'étalonnage
Servizio svizzero di taratura
S Swiss Calibration Service

Accredited by the Swiss Accreditation Service (SAS)
The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: SCS 0108

Client **TüV SÜD UK**

Certificate No: **EX3-3759_Dec17**

CALIBRATION CERTIFICATE

Object: EX3DV4 - SN:3759

Calibration procedure(s): QA CAL-01.v9, QA CAL-12.v9, QA CAL-14.v4, QA CAL-23.v5, QA CAL-25.v6
Calibration procedure for dosimetric E-field probes

Calibration date: December 15, 2017

This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI).
The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature (22 ± 3)°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID	Cal Date (Certificate No.)	Scheduled Calibration
Power meter NRP	SN: 104778	04-Apr-17 (No. 217-02521/02522)	Apr-18
Power sensor NRP-Z91	SN: 103244	04-Apr-17 (No. 217-02521)	Apr-18
Power sensor NRP-Z91	SN: 103245	04-Apr-17 (No. 217-02525)	Apr-18
Reference 20 dB Attenuator	SN: S5277 (20x)	07-Apr-17 (No. 217-02528)	Apr-18
Reference Probe ES3DV2	SN: 3013	31-Dec-16 (No. ES3-3013_Dec16)	Dec-17
DAE4	SN: 654	24-Jul-17 (No. DAE4-654_Jul17)	Jul-18
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-16)	In house check: Jun-18
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-16)	In house check: Jun-18
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-16)	In house check: Jun-18
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-16)	In house check: Jun-18
Network Analyzer HP 8753E	SN: US37390585	18-Oct-01 (in house check Oct-17)	In house check: Oct-18

	Name	Function	Signature
Calibrated by:	Michael Weber	Laboratory Technician	M.Weber
Approved by:	Katja Pokovic	Technical Manager	[signature]

Issued: December 15, 2017

Calibration Laboratory of
Schmid & Partner
Engineering AG
Zeughausstrasse 43, 8004 Zurich, Switzerland

S Schweizerischer Kalibrierdienst
C Service suisse d'étalonnage
S Servizio svizzero di taratura
Swiss Calibration Service

Accredited by the Swiss Accreditation Service (SAS)
The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

Glossary:

TSL	tissue simulating liquid
NORMx,y,z	sensitivity in free space
ConvF	sensitivity in TSL / NORMx,y,z
DCP	diode compression point
CF	crest factor (1/duty_cycle) of the RF signal
A, B, C, D	modulation dependent linearization parameters
Polarization φ	φ rotation around probe axis
Polarization ϑ	ϑ rotation around an axis that is in the plane normal to probe axis (at measurement center), i.e., ϑ = 0 is normal to probe axis
Connector Angle	information used in DASY system to align probe sensor X to the robot coordinate system

Calibration is Performed According to the Following Standards:

a) IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
b) IEC 62209-1, ", "Measurement procedure for the assessment of Specific Absorption Rate (SAR) from hand-held and body-mounted devices used next to the ear (frequency range of 300 MHz to 6 GHz)", July 2016
c) IEC 62209-2, "Procedure to determine the Specific Absorption Rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010
d) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Methods Applied and Interpretation of Parameters:

- *NORMx,y,z:* Assessed for E-field polarization ϑ = 0 (f ≤ 900 MHz in TEM-cell; f > 1800 MHz: R22 waveguide). NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not affect the E^2-field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)x,y,z = NORMx,y,z * frequency_response* (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of *ConvF*.
- *DCPx,y,z:* DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal (no uncertainty required). DCP does not depend on frequency nor media.
- *PAR:* PAR is the Peak to Average Ratio that is not calibrated but determined based on the signal characteristics
- *Ax,y,z; Bx,y,z; Cx,y,z; Dx,y,z; VRx,y,z: A, B, C, D* are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. *VR* is the maximum calibration range expressed in RMS voltage across the diode.
- *ConvF and Boundary Effect Parameters:* Assessed in flat phantom using E-field (or Temperature Transfer Standard for f ≤ 800 MHz) and inside waveguide using analytical field distributions based on power measurements for f > 800 MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to *NORMx,y,z * ConvF* whereby the uncertainty corresponds to that given for *ConvF*. A frequency dependent *ConvF* is used in DASY version 4.4 and higher which allows extending the validity from ± 50 MHz to ± 100 MHz.
- *Spherical isotropy (3D deviation from isotropy)*: in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- *Sensor Offset*: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- *Connector Angle*: The angle is assessed using the information gained by determining the *NORMx* (no uncertainty required).

Probe EX3DV4

SN:3759

Manufactured: March 16, 2010
Calibrated: December 15, 2017

Calibrated for DASY/EASY Systems
(Note: non-compatible with DASY2 system!)

Product Service

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3759

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu V/(V/m)^2$)[A]	0.47	0.43	0.44	± 10.1 %
DCP (mV)[B]	96.3	101.3	104.4	

Modulation Calibration Parameters

UID	Communication System Name		A dB	B dB$\sqrt{\mu V}$	C	D dB	VR mV	Unc[E] (k=2)
0	CW	X	0.0	0.0	1.0	0.00	175.9	±2.7 %
		Y	0.0	0.0	1.0		176.6	
		Z	0.0	0.0	1.0		190.7	

Note: For details on UID parameters see Appendix.

Sensor Model Parameters

	C1 fF	C2 fF	α V^{-1}	T1 $ms.V^{-2}$	T2 $ms.V^{-1}$	T3 ms	T4 V^{-2}	T5 V^{-1}	T6
X	41.32	316.6	37.15	11.64	0.646	5.078	0.000	0.575	1.008
Y	45.97	342.8	35.45	15.74	0.369	5.100	0.925	0.377	1.008
Z	41.91	321.1	37.19	13.86	1.049	5.067	0.000	0.617	1.009

The reported uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

[A] The uncertainties of Norm X,Y,Z do not affect the E^2-field uncertainty inside TSL (see Pages 5 and 6).
[B] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

Product Service

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3759

Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
450	43.5	0.87	11.17	11.17	11.17	0.13	1.20	± 13.3 %
750	41.9	0.89	10.54	10.54	10.54	0.26	1.13	± 12.0 %
835	41.5	0.90	10.15	10.15	10.15	0.20	1.15	± 12.0 %
900	41.5	0.97	9.96	9.96	9.96	0.22	1.12	± 12.0 %
1640	40.2	1.31	8.76	8.76	8.76	0.17	1.00	± 12.0 %
1750	40.1	1.37	8.66	8.66	8.66	0.24	0.87	± 12.0 %
1900	40.0	1.40	8.34	8.34	8.34	0.16	0.99	± 12.0 %
2100	39.8	1.49	8.38	8.38	8.38	0.17	0.90	± 12.0 %
2300	39.5	1.67	7.66	7.66	7.66	0.23	0.86	± 12.0 %
2450	39.2	1.80	7.32	7.32	7.32	0.25	0.86	± 12.0 %
2600	39.0	1.96	7.06	7.06	7.06	0.25	0.92	± 12.0 %
5200	36.0	4.66	4.51	4.51	4.51	0.40	1.80	± 13.1 %
5300	35.9	4.76	4.36	4.36	4.36	0.40	1.80	± 13.1 %
5500	35.6	4.96	3.87	3.87	3.87	0.40	1.80	± 13.1 %
5600	35.5	5.07	3.83	3.83	3.83	0.40	1.80	± 13.1 %
5800	35.3	5.27	3.88	3.88	3.88	0.40	1.80	± 13.1 %

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.

[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

Product Service

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3759

Calibration Parameter Determined in Body Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
450	56.7	0.94	11.45	11.45	11.45	0.05	1.20	± 13.3 %
750	55.5	0.96	10.23	10.23	10.23	0.21	1.15	± 12.0 %
835	55.2	0.97	9.95	9.95	9.95	0.21	1.08	± 12.0 %
900	55.0	1.05	9.83	9.83	9.83	0.17	1.25	± 12.0 %
1640	53.7	1.42	8.79	8.79	8.79	0.26	0.83	± 12.0 %
1750	53.4	1.49	8.24	8.24	8.24	0.28	0.80	± 12.0 %
1900	53.3	1.52	7.95	7.95	7.95	0.14	1.20	± 12.0 %
2100	53.2	1.62	8.35	8.35	8.35	0.22	0.95	± 12.0 %
2300	52.9	1.81	7.64	7.64	7.64	0.26	0.86	± 12.0 %
2450	52.7	1.95	7.49	7.49	7.49	0.25	0.85	± 12.0 %
2600	52.5	2.16	7.20	7.20	7.20	0.22	0.90	± 12.0 %
5200	49.0	5.30	4.03	4.03	4.03	0.40	1.90	± 13.1 %
5300	48.9	5.42	3.88	3.88	3.88	0.40	1.90	± 13.1 %
5500	48.6	5.65	3.38	3.38	3.38	0.45	1.90	± 13.1 %
5600	48.5	5.77	3.29	3.29	3.29	0.45	1.90	± 13.1 %
5800	48.2	6.00	3.34	3.34	3.34	0.45	1.90	± 13.1 %

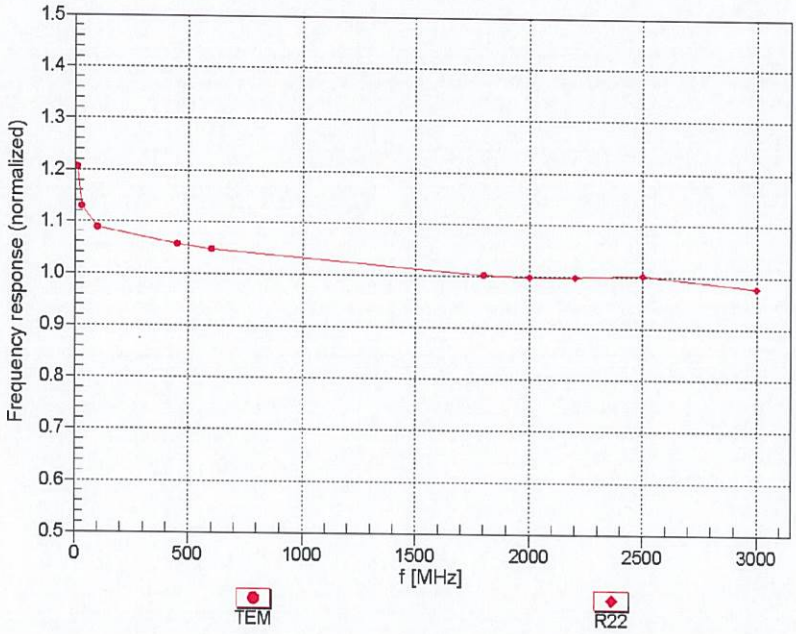
[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.

[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

Frequency Response of E-Field

(TEM-Cell:ifi110 EXX, Waveguide: R22)

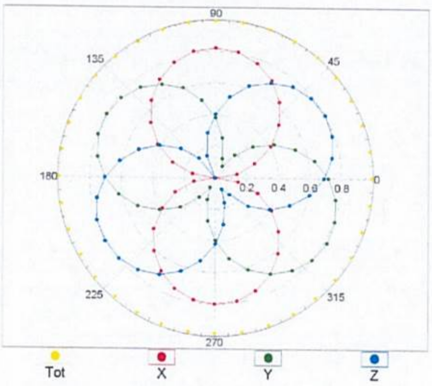


Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

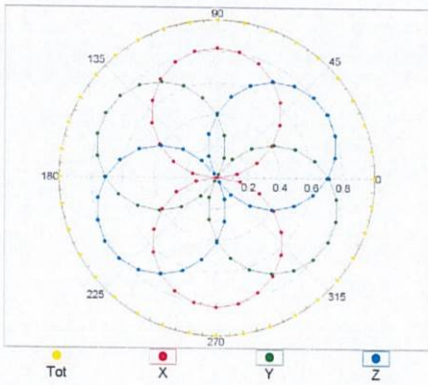
Product Service

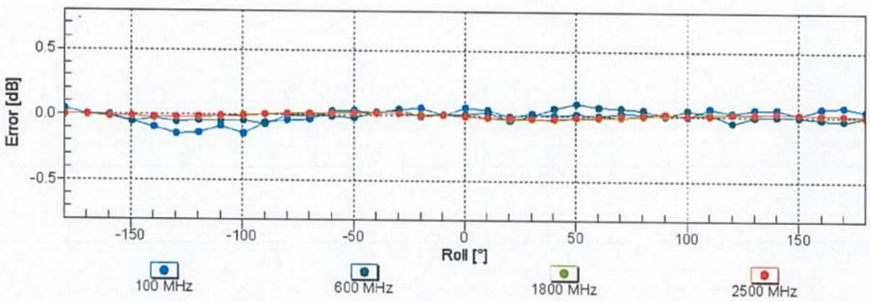
Receiving Pattern (ϕ), $\vartheta = 0°$

f=600 MHz,TEM



f=1800 MHz,R22



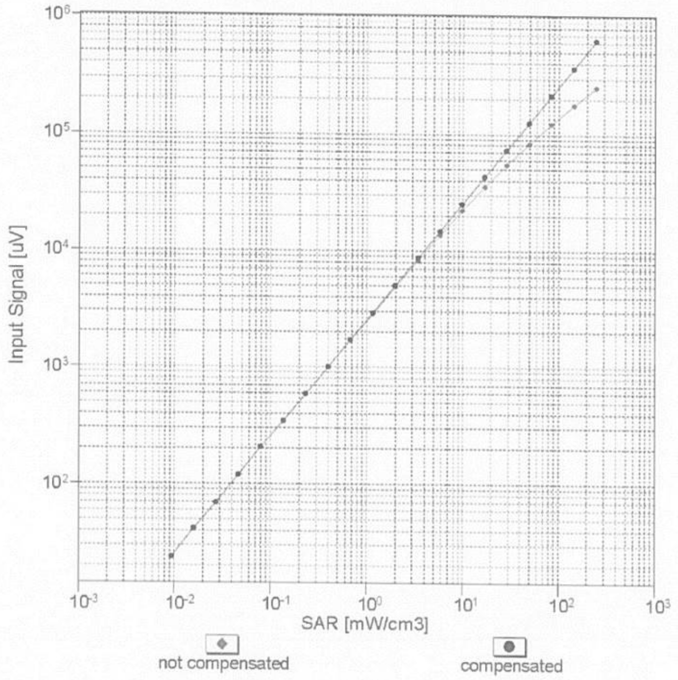


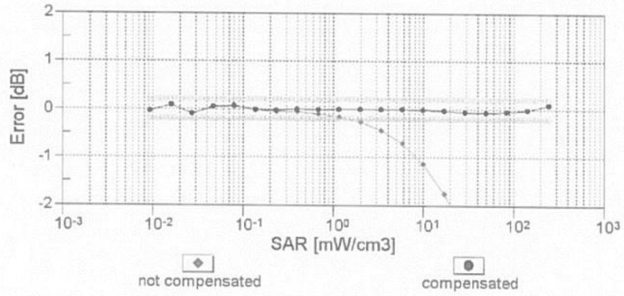
Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

Product Service

Dynamic Range f(SAR_{head})

(TEM cell , f_{eval}= 1900 MHz)

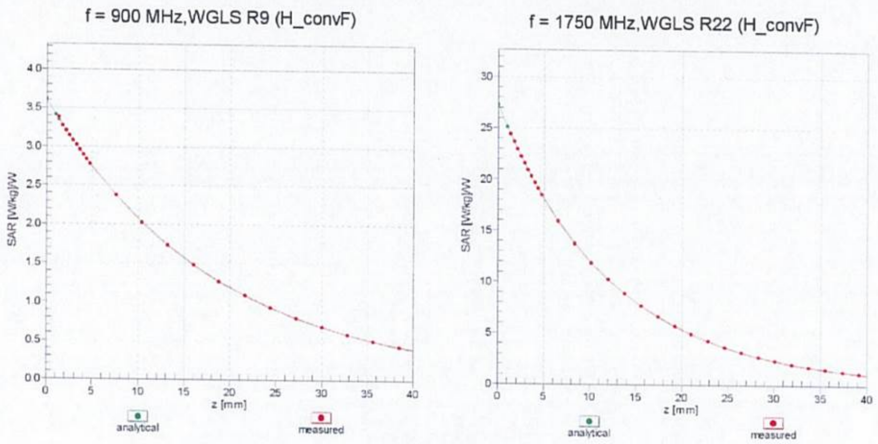




Uncertainty of Linearity Assessment: ± 0.6% (k=2)

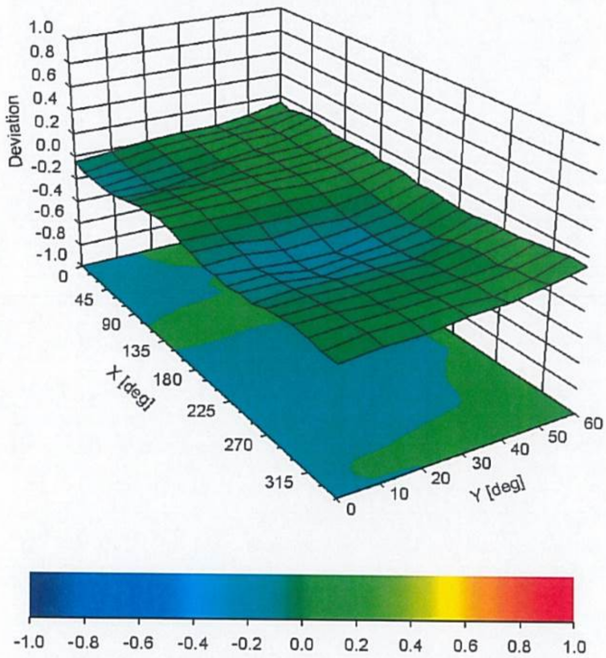
TÜV SÜD Product Service

Conversion Factor Assessment



Deviation from Isotropy in Liquid

Error (ϕ, ϑ), f = 900 MHz



Uncertainty of Spherical Isotropy Assessment: ± 2.6% (k=2)