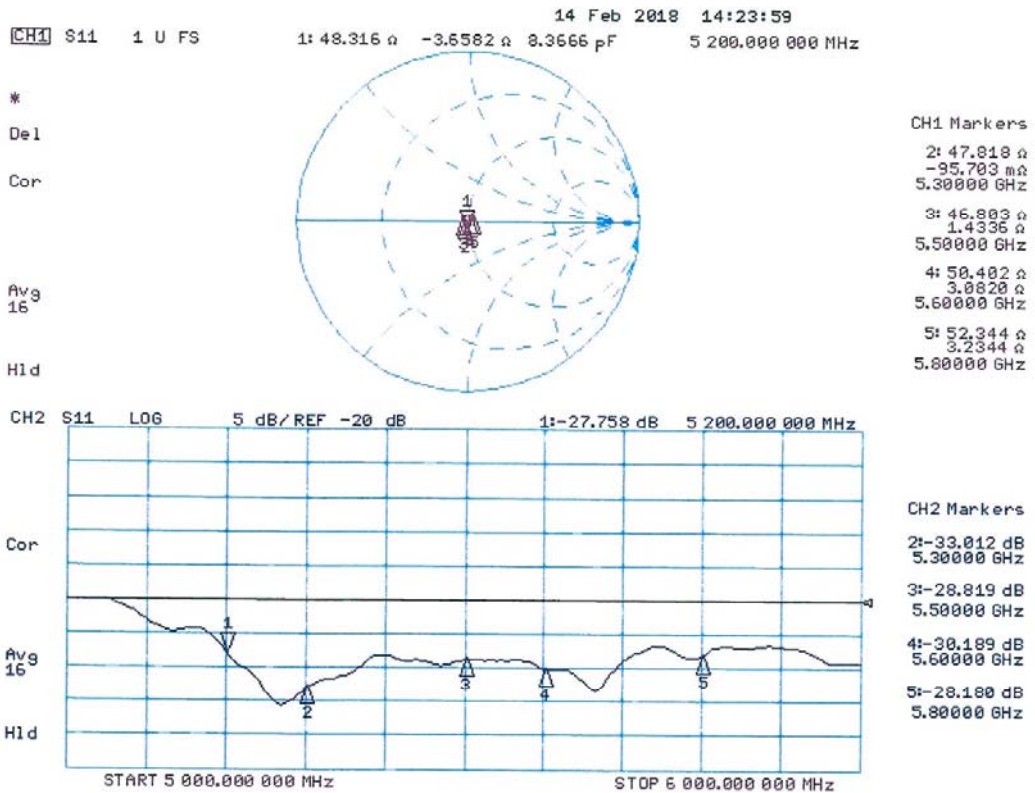


Impedance Measurement Plot for Head TSL



## DASY5 Validation Report for Body TSL

Date: 15.02.2018

Test Laboratory: SPEAG, Zurich, Switzerland

### DUT: Dipole D5GHzV2; Type: D5GHzV2; Serial: D5GHzV2 - SN:1212

Communication System: UID 0 - CW; Frequency: 5200 MHz, Frequency: 5300 MHz,  
Frequency: 5500 MHz, Frequency: 5600 MHz, Frequency: 5800 MHz

Medium parameters used:  $f = 5200$  MHz;  $\sigma = 5.41$  S/m;  $\epsilon_r = 47.5$ ;  $\rho = 1000$  kg/m<sup>3</sup>,

Medium parameters used:  $f = 5300$  MHz;  $\sigma = 5.54$  S/m;  $\epsilon_r = 47.3$ ;  $\rho = 1000$  kg/m<sup>3</sup>,

Medium parameters used:  $f = 5500$  MHz;  $\sigma = 5.8$  S/m;  $\epsilon_r = 47$ ;  $\rho = 1000$  kg/m<sup>3</sup>,

Medium parameters used:  $f = 5600$  MHz;  $\sigma = 5.95$  S/m;  $\epsilon_r = 46.8$ ;  $\rho = 1000$  kg/m<sup>3</sup>,

Medium parameters used:  $f = 5800$  MHz;  $\sigma = 6.23$  S/m;  $\epsilon_r = 46.4$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

#### DASY52 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(5.35, 5.35, 5.35); Calibrated: 30.12.2017, ConvF(5.15, 5.15, 5.15);  
Calibrated: 30.12.2017, ConvF(4.7, 4.7, 4.7); Calibrated: 30.12.2017, ConvF(4.65, 4.65, 4.65);  
Calibrated: 30.12.2017, ConvF(4.53, 4.53, 4.53); Calibrated: 30.12.2017;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 26.10.2017
- Phantom: Flat Phantom 5.0 (back); Type: QD 000 P50 AA; Serial: 1002
- DASY52 52.10.0(1446); SEMCAD X 14.6.10(7417)

#### Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5200 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 64.59 V/m; Power Drift = -0.02 dB

Peak SAR (extrapolated) = 27.2 W/kg

**SAR(1 g) = 7.31 W/kg; SAR(10 g) = 2.03 W/kg**

Maximum value of SAR (measured) = 16.9 W/kg

#### Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5300 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 64.99 V/m; Power Drift = -0.01 dB

Peak SAR (extrapolated) = 29.6 W/kg

**SAR(1 g) = 7.57 W/kg; SAR(10 g) = 2.11 W/kg**

Maximum value of SAR (measured) = 17.7 W/kg

#### Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5500 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 65.88 V/m; Power Drift = -0.07 dB

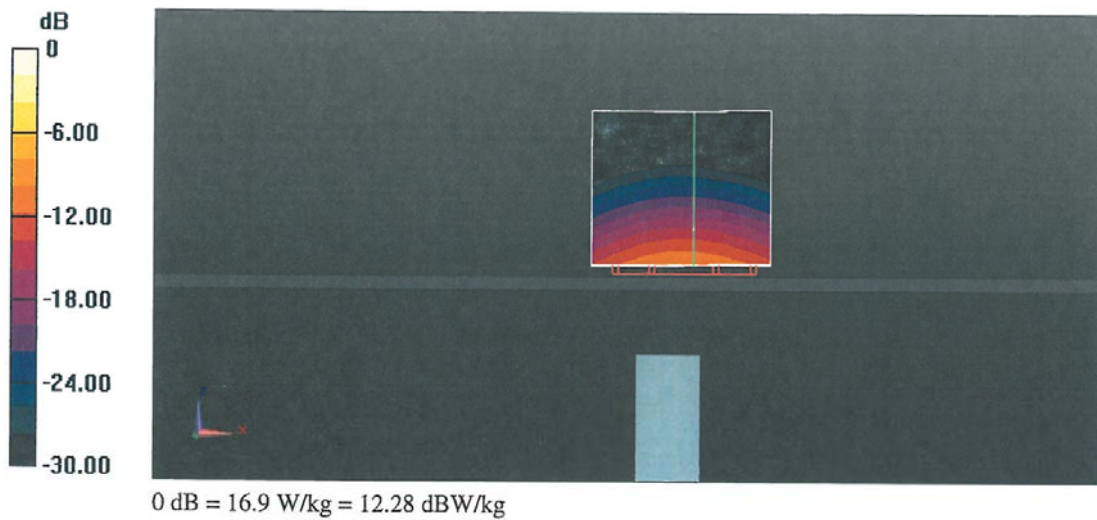
Peak SAR (extrapolated) = 33.3 W/kg

**SAR(1 g) = 8.04 W/kg; SAR(10 g) = 2.22 W/kg**

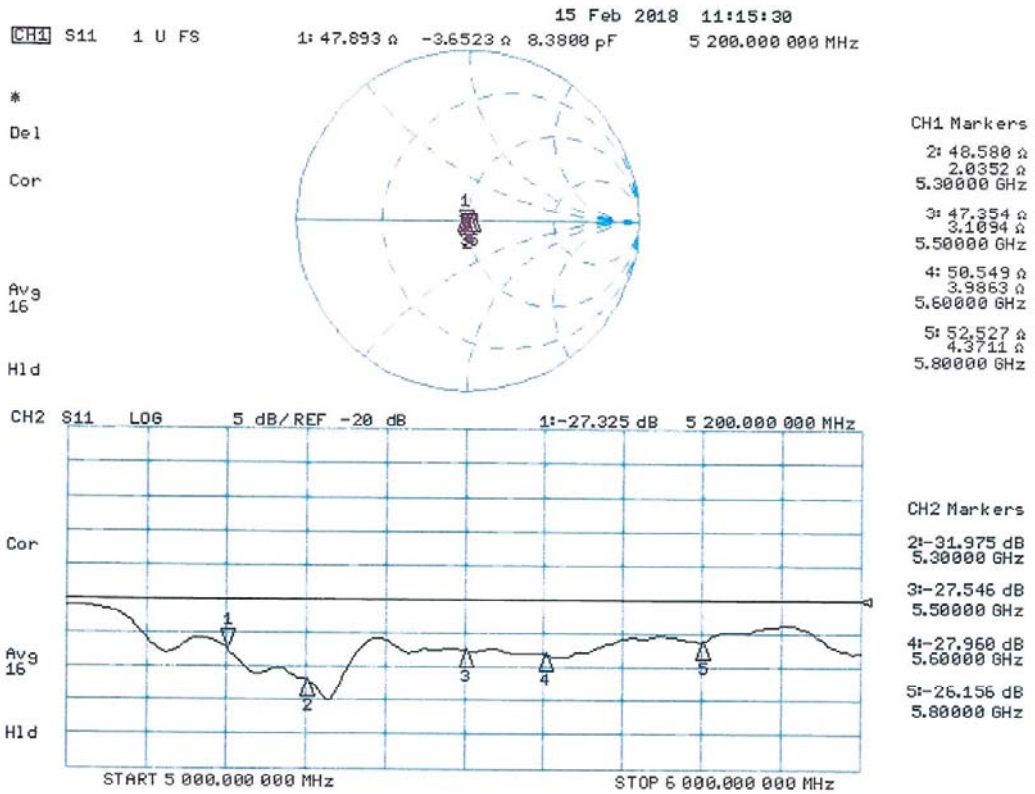
Maximum value of SAR (measured) = 19.3 W/kg

**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5600 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm  
Reference Value = 64.59 V/m; Power Drift = -0.02 dB  
Peak SAR (extrapolated) = 33.4 W/kg  
**SAR(1 g) = 7.94 W/kg; SAR(10 g) = 2.2 W/kg**  
Maximum value of SAR (measured) = 19.0 W/kg

**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5800 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm  
Reference Value = 63.42 V/m; Power Drift = -0.02 dB  
Peak SAR (extrapolated) = 33.2 W/kg  
**SAR(1 g) = 7.62 W/kg; SAR(10 g) = 2.1 W/kg**  
Maximum value of SAR (measured) = 18.7 W/kg



Impedance Measurement Plot for Body TSL



## APPENDIX C. – SAR Tissue Specifications



The brain and muscle mixtures consist of a viscous gel using hydrox-ethylcellulose (HEC) gelling agent and saline solution (see Table 3.1). Preservation with a bactericide is added and visual inspection is made to make sure air bubbles are not trapped during the mixing process. The mixture is calibrated to obtain proper dielectric constant (permittivity) and conductivity of the desired tissue. The mixture characterizations used for the brain and muscle tissue simulating liquids are according to the data by C. Gabriel and G. Harts grove.



**Figure 3.9 Simulated Tissue**

**Table C.1 Composition of the Tissue Equivalent Matter**

Ingredients (% by weight)	Frequency (MHz)							
	835		1900		2450		5200 ~ 5800	
Tissue Type	Head	Body	Head	Body	Head	Body	Head	Body
Water	40.19	50.75	55.24	70.23	71.88	73.40	65.52	80.00
Salt (NaCl)	1.480	0.940	0.310	0.290	0.160	0.060	-	-
Sugar	57.90	48.21	-	-	-	-	-	-
HEC	0.250	-	-	-	-	-	-	-
Bactericide	0.180	0.100	-	-	-	-	-	-
Triton X-100	-	-	-	-	19.97	-	17.24	-
DGBE	-	-	44.45	29.48	7.990	26.54	-	-
Diethylene glycol hexyl ether	-	-	-	-	-	-	17.24	-
Polysorbate (Tween) 80	-	-	-	-	-	-	-	20.00
Target for Dielectric Constant	41.5	55.2	40.0	53.3	39.2	52.7	-	-
Target for Conductivity (S/m)	0.90	0.97	1.40	1.52	1.80	1.95	-	-

Salt:	99 % Pure Sodium Chloride	Sugar:	98 % Pure Sucrose
Water:	De-ionized, 16M resistivity	HEC:	Hydroxyethyl Cellulose
DGBE:	99 % Di(ethylene glycol) butyl ether,[2-(2-butoxyethoxy) ethanol]		
Triton X-100(ultra pure):	Polyethylene glycol mono[4-(1,1,3,3-tetramethylbutyl)phenyl] ether		

## APPENDIX D. – SAR SYSTEM VALIDATION

## SAR System Validation

Per FCC KDB 865664 D02v01r02, SAR system validation status should be documented to confirm measurement accuracy. The SAR systems (including SAR probes, system components and software versions) used for this device were validated against its performance specifications prior to the SAR measurements. Reference dipoles were used with the required tissue- equivalent media for system validation, according to the procedures outlined in FCC KDB 865664 D01v01r04 and IEEE 1528-2013. Since SAR probe calibrations are frequency dependent, each probe calibration point was validated at a frequency within the valid frequency range of the probe calibration point, using the system that normally operates with the probe for routine SAR measurements and according to the required tissue-equivalent media.

A tabulated summary of the system validation status including the validation date(s), measurement frequencies, SAR probes and tissue dielectric parameters has been included.

**Table D.1 SAR System Validation Summary**

SAR System	Freq. [MHz]	Date	Probe SN	Probe Type	Probe CAL. Point		PERM.	COND.	CW Validation			MOD. Validation		
							( $\epsilon_r$ )	( $\sigma$ )	Sensitivity	Probe Linearity	Probe Isortopy	MOD. Type	Duty Factor	PAR
D	2450	2018.09.21	3327	ES3DV3	2450	Head	39.443	1.815	PASS	PASS	PASS	OFDM/TDD	PASS	PASS
D	5200	2018.06.12	3866	EX3DV4	5200	Head	35.442	4.715	PASS	PASS	PASS	OFDM	N/A	PASS
D	5300	2018.06.12	3866	EX3DV4	5300	Head	35.216	4.815	PASS	PASS	PASS	OFDM	N/A	PASS
D	5500	2018.06.13	3866	EX3DV4	5500	Head	35.056	5.015	PASS	PASS	PASS	OFDM	N/A	PASS
D	5600	2018.06.13	3866	EX3DV4	5600	Head	34.915	5.212	PASS	PASS	PASS	OFDM	N/A	PASS
D	5800	2018.06.14	3866	EX3DV4	5800	Head	34.826	5.336	PASS	PASS	PASS	OFDM	N/A	PASS
D	2450	2018.09.21	3327	ES3DV3	2450	Body	52.226	2.011	PASS	PASS	PASS	OFDM/TDD	PASS	PASS
D	5200	2018.06.12	3866	EX3DV4	5200	Body	48.884	5.446	PASS	PASS	PASS	OFDM	N/A	PASS
D	5300	2018.06.12	3866	EX3DV4	5300	Body	48.226	5.516	PASS	PASS	PASS	OFDM	N/A	PASS
D	5500	2018.06.13	3866	EX3DV4	5500	Body	47.886	5.779	PASS	PASS	PASS	OFDM	N/A	PASS
D	5600	2018.06.13	3866	EX3DV4	5600	Body	47.514	5.836	PASS	PASS	PASS	OFDM	N/A	PASS
D	5800	2018.06.14	3866	EX3DV4	5800	Body	47.224	6.223	PASS	PASS	PASS	OFDM	N/A	PASS

NOTE: While the probes have been calibrated for both a CW and modulated signals, all measurements were performed using communication systems calibrated for CW signals only. Modulations in the table above represent test configurations for which the measurement system has been validated per FCC KDB Publication 865664 D01v01r04 for scenarios when CW probe calibrations are used with other signal types. SAR systems were validated for modulated signals with a periodic duty cycle, such as GMSK, or with a high peak to average ratio (>5 dB), such as OFDM according to KDB 865664.

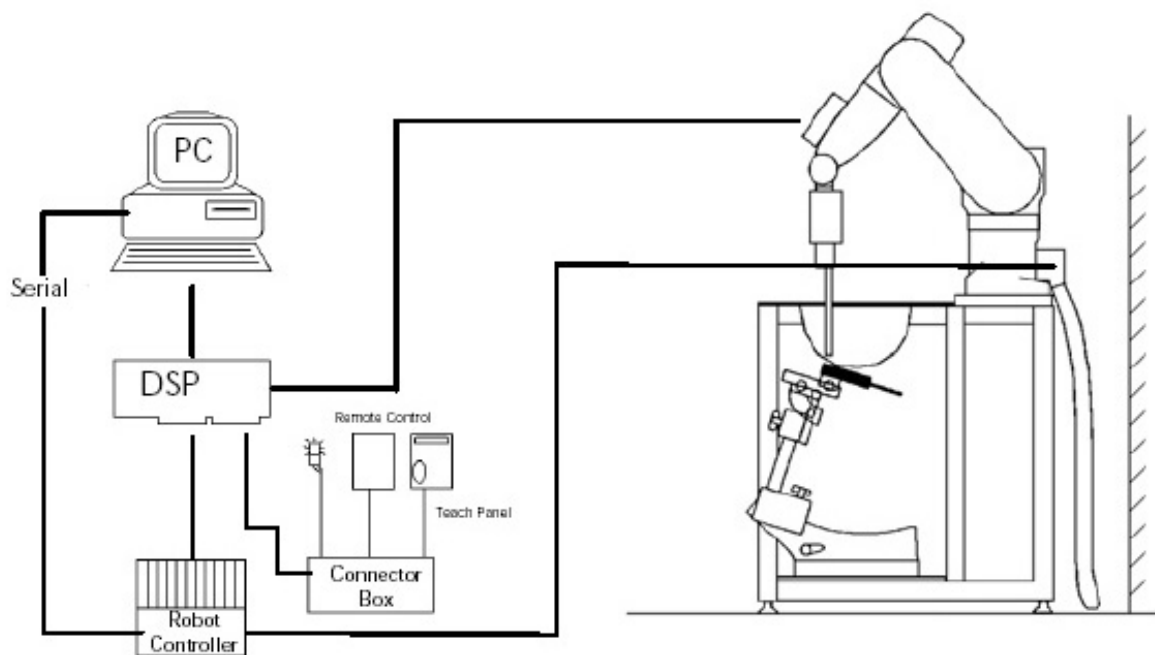


## APPENDIX E. – Description of Test Equipment

## E.1 SAR Measurement Setup

Measurements are performed using the DASY5 automated dosimetric assessment system. The DASY5 is made by Schmid & Partner Engineering AG (SPEAG) in Zurich, Switzerland and consists of high precision robotics system (Staubli), robot controller, desktop computer, near-field probe, probe alignment sensor, and the generic twin phantom containing the brain equivalent material. The robot is a six-axis industrial robot performing precise movements to position the probe to the location (points) of maximum electromagnetic field (EMF) (see Fig. E.1.1).

A cell controller system contains the power supply, robot controller each pendant (Joystick), and a remote control used to drive the robot motors. The PC consists of the Intel Core i7-3770 3.40 GHz desktop computer with Windows 7 system and SAR Measurement Software DASY5, A/D interface card, monitor, mouse, and keyboard. The Staubli Robot is connected to the cell controller to allow software manipulation of the robot. A data acquisition electronic (DAE) circuit that performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. is connected to the Electro-optical coupler (EOC). The EOC performs the conversion from the optical into digital electric signal of the DAE and transfers data to the PC plug-in card.

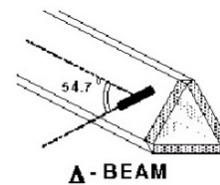


**Figure E.1.1 SAR Measurement System Setup**

The DAE4 consists 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 and control logic unit. Transmission to the PC-card is accomplished through an optical downlink for data and status information and an optical uplink for commands and clock lines. The mechanical probe mounting device includes two different sensor systems for frontal and sidewise probe contacts. They are also used for mechanical surface detection and probe collision detection. The robot uses its own controller with a built in VME-bus computer. The system is described in detail.

**E.2 Probe Specification**

<b>Calibration</b>	In air from 10 MHz to 4 GHz/10 MHz to 6 GHz In brain and muscle simulating tissue at Frequencies of 750 MHz, 835 MHz, 900 MHz, 1750 MHz, 1900 MHz, 2450 MHz, 2600 MHz  750 MHz, 835 MHz, 900 MHz, 1750 MHz, 1900 MHz, 2300 MHz, 2450 MHz, 2600 MHz, 3500 MHz, 5200 MHz, 5300 MHz, 5500 MHz, 5600 MHz, 5800 MHz
<b>Frequency</b>	10 MHz to 4 GHz/10 MHz to 6 GHz
<b>Linearity</b>	± 0.2 dB(30 MHz to 4 GHz/30 MHz to 6 GHz)
<b>Dynamic</b>	10 µW/g to > 100 mW/g
<b>Range</b>	Linearity : ±0.2dB
<b>Dimensions</b>	Overall length : 337 mm
<b>Tip length</b>	20 mm
<b>Body diameter</b>	12 mm
<b>Tip diameter</b>	3.9 mm/2.5 mm
<b>Distance from probe tip to sensor center</b>	2.0 mm/1.0 mm
<b>Application</b>	SAR Dosimetry Testing Compliance tests of mobile phones



**Figure E.2.1 Triangular Probe Configurations**



**Figure E.2.2 Probe Thick-Film Technique**



**DAE System**

The SAR measurements were conducted with the dosimetric probe ES3DV3 and EX3DV4 designed in the classical triangular configuration(see E.2.1) and optimized for dosimetric evaluation. The probe is constructed using the thick film technique; with printed resistive lines on ceramic substrates. The probe is equipped with an optical multitier line ending at the front of the probe tip. It is connected to the EOC box on the robot arm and provides an automatic detection of the phantom surface. Half of the fibers are connected to a pulsed infrared transmitter, the other half to a synchronized receiver. As the probe approaches the surface, the reflection from the surface produces a coupling from the transmitting to the receiving fibers. This reflection increases first during the approach, reaches maximum and then decreases. If the probe is flatly touching the surface, the coupling is zero. The distance of the coupling maximum to the surface is independent of the surface reflectivity and largely independent of the surface to probe angle. The DASY5 software reads the reflection during a software approach and looks for the maximum using a 2nd order fitting. The approach is stopped at reaching the maximum.

### E.3 E-Probe Calibration Process

#### Dosimetric Assessment Procedure

Each probe is calibrated according to a dosimetric assessment procedure with accuracy better than +/- 10%. The spherical isotropy was evaluated with the procedure and found to be better than +/-0.25dB. The sensitivity parameters (Norm X, Norm Y, Norm Z), the diode compression parameter (DCP) and the conversion factor (Conv F) of the probe is tested.

#### Free Space Assessment

The free space E-field from amplified probe outputs is determined in a test chamber. This is performed in a TEM cell for frequencies below 1 GHz, and in a waveguide above 1GHz for free space. For the free space calibration, the probe is placed in the volumetric center of the cavity at the proper orientation with the field. The probe is then rotated 360 degrees.

#### Temperature Assessment \*

E-field temperature correlation calibration is performed in a flat phantom filled with the appropriate simulated brain tissue. The measured free space E-field in the medium, correlates to temperature rise in a dielectric medium. For temperature correlation calibration a RF transparent the remits or based temperature probe is used in conjunction with the E-field probe.

$$SAR = C \frac{\Delta T}{\Delta t}$$

$$SAR = \frac{|E|^2 \cdot \sigma}{\rho}$$

where:

where:

$\Delta t$  = exposure time (30 seconds),

$\sigma$  = simulated tissue conductivity,

C = heat capacity of tissue (brain or muscle),

$\rho$  = Tissue density (1.25 g/cm<sup>3</sup> for brain tissue)

$\Delta T$  = temperature increase due to RF exposure.

SAR is proportional to  $\Delta T / \Delta t$ , the initial rate of tissue heating, before thermal diffusion takes place. Now it's possible to quantify the electric field in the simulated tissue by equating the thermally derived SAR to the E- field;

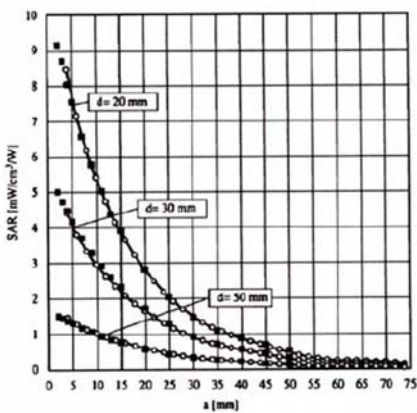


Figure E.3.1 E-Field and Temperature Measurements at 900MHz

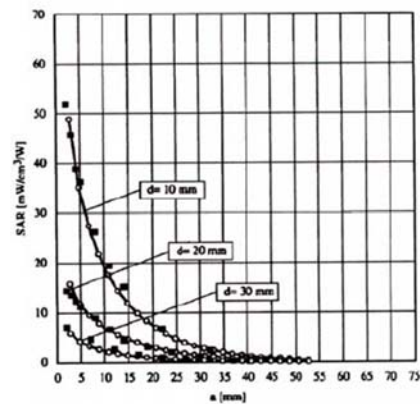


Figure E.3.2 E-Field and Temperature Measurements at 1800MHz

## E.4 Data Extrapolation

The DASY5 software automatically executes the following procedures to calculate the field units from the microvolt readings at the probe connector. The first step of the evaluation is a linearization of the filtered input signal to account for the compression characteristics of the detector diode. The compensation depends on the input signal, the diode type and the DC-transmission factor from the diode to the evaluation electronics. If the exciting field is pulsed, the crest factor of the signal must be known to correctly compensate for peak power. The formula for each channel can be given like below;

$$V_i = U_i + U_i^2 \cdot \frac{cf}{dcp_i}$$

with

- $V_i$  = compensated signal of channel i (i=x,y,z)
- $U_i$  = input signal of channel i (i=x,y,z)
- cf = crest factor of exciting field (DASY parameter)
- dcp<sub>i</sub> = diode compression point (DASY parameter)

From the compensated input signals the primary field data for each channel can be evaluated:

E-field probes:

$$E_i = \sqrt{\frac{V_i}{Norm_i \cdot ConvF}}$$

with

- $V_i$  = compensated signal of channel i (i = x,y,z)
- Norm<sub>i</sub> = sensor sensitivity of channel i (i = x,y,z)  
μV/(V/m)<sup>2</sup> for E-field probes
- ConvF = sensitivity of enhancement in solution
- $E_i$  = electric field strength of channel i in V/m

The RSS value of the field components gives the total field strength (Hermetian magnitude):

$$E_{tot} = \sqrt{E_x^2 + E_y^2 + E_z^2}$$

The primary field data are used to calculate the derived field units.

$$SAR = E_{tot}^2 \cdot \frac{\sigma}{\rho \cdot 1000}$$

with

- SAR = local specific absorption rate in W/g
- $E_{tot}$  = total field strength in V/m
- $\sigma$  = conductivity in [mho/m] or [Siemens/m]
- $\rho$  = equivalent tissue density in g/cm<sup>3</sup>

The power flow density is calculated assuming the excitation field to be a free space field.

$$P_{free} = \frac{E_{tot}^2}{3770}$$

with

- $P_{pwe}$  = equivalent power density of a plane wave in W/cm<sup>2</sup>
- $E_{tot}$  = total electric field strength in V/m

## E.5 SAM Twin Phantom

The SAM Twin Phantom V5.0 is constructed of a fiberglass shell integrated in a wooden table. The shape of the shell is based on data from an anatomical study designed to determine the maximum exposure in at least 90% of all users. It enables the dosimetric evaluation of left and right hand phone usage as well as body mounted usage at the flat phantom region. A cover prevents the evaporation of the liquid.

Reference markings on the Phantom allow the complete setup of all predefined phantom positions and measurement grids by manually teaching three points in the robot. (see Fig. E.5.1)



**Figure E.5.1 SAM Twin Phantom**

### SAM Twin Phantom Specification:

<b>Construction</b>	The shell corresponds to the specifications of the Specific Anthropomorphic Mannequin (SAM) phantom defined in IEEE 1528 and IEC 62209-1. It enables the dosimetric evaluation of left and right hand phone usage as well as body mounted usage at the flat phantom region. A cover prevents evaporation of the liquid. Reference markings on the phantom allow the complete setup of all predefined phantom positions and measurement grids by teaching three points with the robot. Twin SAM V5.0 has the same shell geometry and is manufactured from the same material as Twin SAM V4.0, but has reinforced top structure.
<b>Shell Thickness</b>	$2 \pm 0.2$ mm
<b>Filling Volume</b>	Approx. 25 liters
<b>Dimensions</b>	Length: 1000 mm Width: 500 mm Height: adjustable feet

### Specific Anthropomorphic Mannequin (SAM) Specifications:

The phantom for handset SAR assessment testing is a low-loss dielectric shell, with shape and dimensions derived from the anthropometric data of the 90th percentile adult male head dimensions as tabulated by the US Army. The SAM Twin Phantom shell is bisected along the mid-sagittal plane into right and left halves (see Fig. E.5.2). The perimeter sidewalls of each phantom halves are extended to allow filling with liquid to a depth that is sufficient to minimized reflections from the upper surface. The liquid depth is maintained at a minimum depth of 15cm to minimize reflections from the upper surface.



**Figure E.5.2 Sam Twin Phantom shell**



## E.6 Device Holder for Transmitters

In combination with the Twin SAM Phantom V4.0/V4.0c, V5.0 or ELI4, the Mounting Device enables the rotation of the mounted transmitter device in spherical coordinates. Rotation point is the ear opening point. Transmitter devices can be easily and accurately positioned according to IEC, IEEE, FCC or other specifications. The device holder can be locked for positioning at different phantom sections (left head, right head, flat).

Note: A simulating human hand is not used due to the complex anatomical and geometrical structure of the hand that may produce infinite number of configurations. To produce the worst-case condition (the hand absorbs antenna output power), the hand is omitted during the tests.



**Figure E.6.1 Mounting Device**

## E.7 Automated Test System Specifications

### Positioner

<b>Robot</b>	Stäubli Unimation Corp. Robot Model: TX90L
<b>Repeatability</b>	0.02 mm
<b>No. of axis</b>	6

### Data Acquisition Electronic (DAE) System

#### Cell Controller

<b>Processor</b>	Intel Core i7-3770
<b>Clock Speed</b>	3.40 GHz
<b>Operating System</b>	Windows 7 Professional
<b>Data Card</b>	DASY5 PC-Board

#### Data Converter

<b>Features</b>	Signal, multiplexer, A/D converter. & control logic
<b>Software</b>	DASY5
<b>Connecting Lines</b>	Optical downlink for data and status info Optical uplink for commands and clock

#### PC Interface Card

<b>Function</b>	24 bit (64 MHz) DSP for real time processing Link to DAE 4 16 bit A/D converter for surface detection system serial link to robot direct emergency stop output for robot
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#### E-Field Probes

<b>Model</b>	ES3DV3 S/N: 3327, EX3DV4 S/N: 3866
<b>Construction</b>	Triangular core fiber optic detection system
<b>Frequency</b>	10 MHz to 4 GHz/10 MHz to 6 GHz
<b>Linearity</b>	$\pm 0.2$ dB (30 MHz to 4 GHz/30 MHz to 6 GHz)

#### Phantom

<b>Phantom</b>	SAM Twin Phantom (V5.0)
<b>Shell Material</b>	Composite
<b>Thickness</b>	$2.0 \pm 0.2$ mm



**Figure E.7.1 DASY5 Test System**