

Measurement Conditions

DASY system configuration, as far as not given on page 1.

DASY Version	DASY5	V52.10.4
Extrapolation	Advanced Extrapolation	
Phantom	Modular Flat Phantom	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	dx, dy = 4 mm, dz = 1.4 mm	Graded Ratio = 1.4 (Z direction)
Frequency	3700 MHz \pm 1 MHz	

Head TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	37.7	3.12 mho/m
Measured Head TSL parameters	(22.0 \pm 0.2) °C	38.4 \pm 6 %	3.09 mho/m \pm 6 %
Head TSL temperature change during test	< 0.5 °C	----	----

SAR result with Head TSL

SAR averaged over 1 cm³ (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	6.72 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	67.6 W/kg \pm 19.9 % (k=2)

SAR averaged over 10 cm³ (10 g) of Head TSL	condition	
SAR measured	100 mW input power	2.43 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	24.4 W/kg \pm 19.5 % (k=2)

Appendix (Additional assessments outside the scope of SCS 0108)

Antenna Parameters with Head TSL

Impedance, transformed to feed point	49.2 Ω - 7.1 j Ω
Return Loss	- 22.9 dB

General Antenna Parameters and Design

Electrical Delay (one direction)	1.138 ns
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After long term use with 100W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard.

No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feedpoint may be damaged.

Additional EUT Data

Manufactured by	SPEAG
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DASY5 Validation Report for Head TSL

Date: 25.11.2020

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 3700 MHz; Type: D3700V2; Serial: D3700V2 - SN:1008

Communication System: UID 0 - CW; Frequency: 3700 MHz

Medium parameters used: $f = 3700$ MHz; $\sigma = 3.09$ S/m; $\epsilon_r = 38.4$; $\rho = 1000$ kg/m³

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(7.73, 7.73, 7.73) @ 3700 MHz; Calibrated: 31.12.2019
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 02.11.2020
- Phantom: Flat Phantom 5.0 (front); Type: QD 000 P50 AA; Serial: 1001
- DASY52 52.10.4(1527); SEMCAD X 14.6.14(7483)

Dipole Calibration for Head Tissue/Pin=100 mW, d=10mm, f=3700MHz/Zoom Scan,

dist=1.4mm (8x8x8)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 70.87 V/m; Power Drift = 0.02 dB

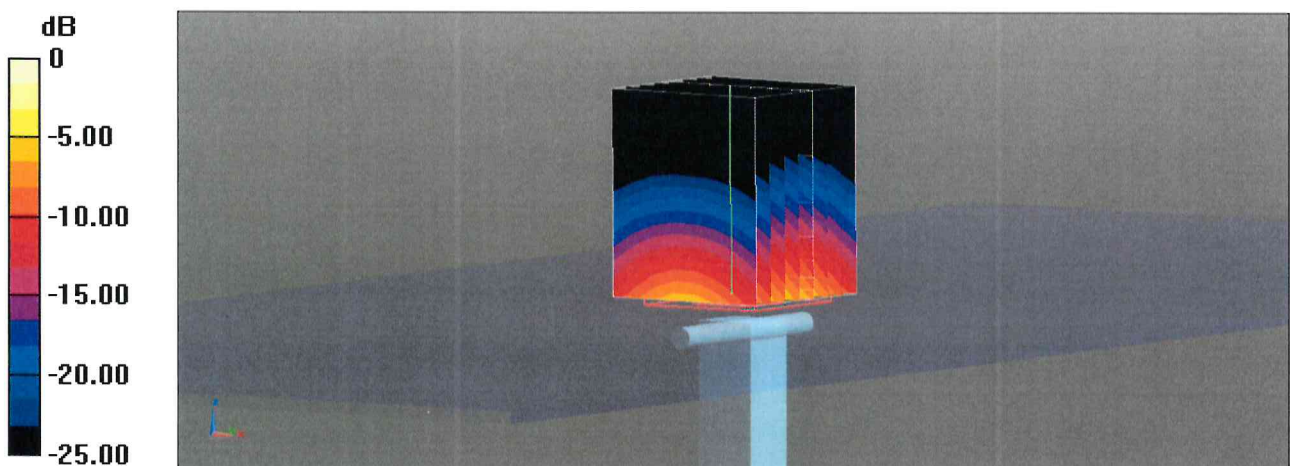
Peak SAR (extrapolated) = 19.0 W/kg

SAR(1 g) = 6.72 W/kg; SAR(10 g) = 2.43 W/kg

Smallest distance from peaks to all points 3 dB below = 8 mm

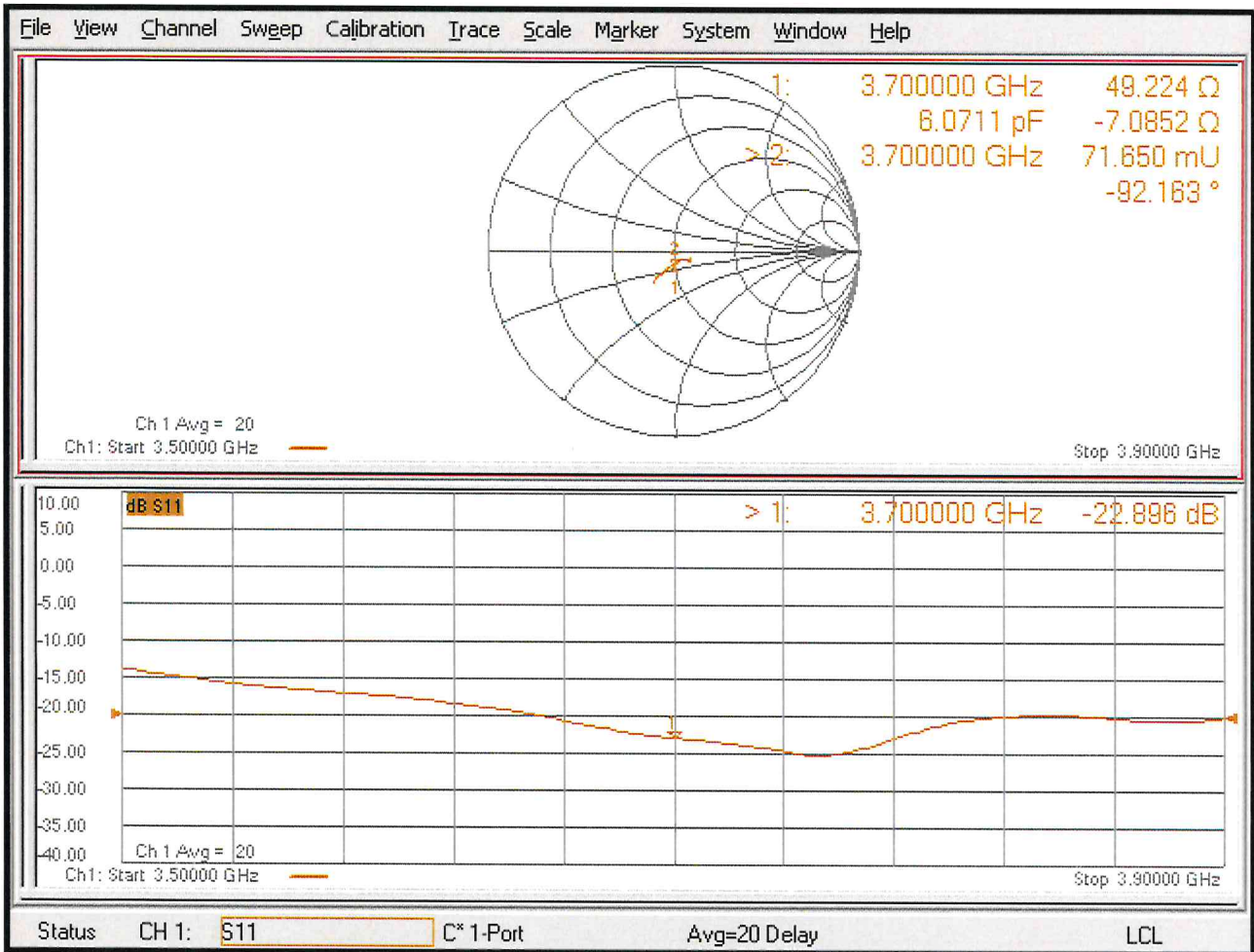
Ratio of SAR at M2 to SAR at M1 = 73.5%

Maximum value of SAR (measured) = 13.2 W/kg



0 dB = 13.2 W/kg = 11.21 dBW/kg

Impedance Measurement Plot for Head TSL





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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

Client **Sporton**

Certificate No: **D3900V2-1048_May20**

CALIBRATION CERTIFICATE

Object **D3900V2 - SN:1048**

Calibration procedure(s) **QA CAL-22.v4
Calibration Procedure for SAR Validation Sources between 3-6 GHz**

Calibration date: **May 14, 2020**

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 ± 5)°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	01-Apr-20 (No. 217-03100/03101)	Apr-21
Power sensor NRP-Z91	SN: 103244	01-Apr-20 (No. 217-03100)	Apr-21
Power sensor NRP-Z91	SN: 103245	01-Apr-20 (No. 217-03101)	Apr-21
Reference 20 dB Attenuator	SN: BH9394 (20k)	31-Mar-20 (No. 217-03106)	Apr-21
Type-N mismatch combination	SN: 310982 / 06327	31-Mar-20 (No. 217-03104)	Apr-21
Reference Probe EX3DV4	SN: 3503	31-Dec-19 (No. EX3-3503_Dec19)	Dec-20
DAE4	SN: 601	27-Dec-19 (No. DAE4-601_Dec19)	Dec-20

Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB39512475	30-Oct-14 (in house check Feb-19)	In house check: Oct-20
Power sensor HP 8481A	SN: US37292783	07-Oct-15 (in house check Oct-18)	In house check: Oct-20
Power sensor HP 8481A	SN: MY41092317	07-Oct-15 (in house check Oct-18)	In house check: Oct-20
RF generator R&S SMT-06	SN: 100972	15-Jun-15 (in house check Oct-18)	In house check: Oct-20
Network Analyzer Agilent E8358A	SN: US41080477	31-Mar-14 (in house check Oct-19)	In house check: Oct-20

	Name	Function	Signature
Calibrated by:	Jeton Kastrati	Laboratory Technician	
Approved by:	Katja Pokovic	Technical Manager	

Issued: May 14, 2020

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Accreditation No.: **SCS 0108**

Glossary:

TSL	tissue simulating liquid
ConvF	sensitivity in TSL / NORM x,y,z
N/A	not applicable or not measured

Calibration is Performed According to the Following Standards:

- 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
- 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
- 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
- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Additional Documentation:

- DASY4/5 System Handbook

Methods Applied and Interpretation of Parameters:

- Measurement Conditions:** Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- Antenna Parameters with TSL:** The dipole is mounted with the spacer to position its feed point exactly below the center marking of the flat phantom section, with the arms oriented parallel to the body axis.
- Feed Point Impedance and Return Loss:** These parameters are measured with the dipole positioned under the liquid filled phantom. The impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- Electrical Delay:** One-way delay between the SMA connector and the antenna feed point. No uncertainty required.
- SAR measured:** SAR measured at the stated antenna input power.
- SAR normalized:** SAR as measured, normalized to an input power of 1 W at the antenna connector.
- SAR for nominal TSL parameters:** The measured TSL parameters are used to calculate the nominal SAR result.

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%.

Measurement Conditions

DASY system configuration, as far as not given on page 1.

DASY Version	DASY5	V52.10.4
Extrapolation	Advanced Extrapolation	
Phantom	Modular Flat Phantom V5.0	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	dx, dy = 4.0 mm, dz = 1.4 mm	Graded Ratio = 1.4 (Z direction)
Frequency	3900 MHz \pm 1 MHz 4100 MHz \pm 1 MHz	

Head TSL parameters at 3900 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	37.5	3.32 mho/m
Measured Head TSL parameters	(22.0 \pm 0.2) °C	36.4 \pm 6 %	3.21 mho/m \pm 6 %
Head TSL temperature change during test	< 0.5 °C	---	---

SAR result with Head TSL at 3900 MHz

SAR averaged over 1 cm ³ (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	7.03 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	70.2 W/kg \pm 19.9 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Head TSL	condition	
SAR measured	100 mW input power	2.45 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	24.4 W/kg \pm 19.5 % (k=2)

Head TSL parameters at 4100 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	37.2	3.53 mho/m
Measured Head TSL parameters	(22.0 \pm 0.2) °C	36.2 \pm 6 %	3.39 mho/m \pm 6 %
Head TSL temperature change during test	< 0.5 °C	---	---

SAR result with Head TSL at 4100 MHz

SAR averaged over 1 cm ³ (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	6.89 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	68.9 W/kg \pm 19.9 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Head TSL	condition	
SAR measured	100 mW input power	2.39 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	23.7 W/kg \pm 19.5 % (k=2)

Appendix (Additional assessments outside the scope of SCS 0108)

Antenna Parameters with Head TSL at 3900 MHz

Impedance, transformed to feed point	48.6 Ω - 3.2 j Ω
Return Loss	- 29.1 dB

Antenna Parameters with Head TSL at 4100 MHz

Impedance, transformed to feed point	59.7 Ω + 1.3 j Ω
Return Loss	- 21.0 dB

General Antenna Parameters and Design

Electrical Delay (one direction)	1.106 ns
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After long term use with 100W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard.

No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feedpoint may be damaged.

Additional EUT Data

Manufactured by	SPEAG
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DASY5 Validation Report for Head TSL

Date: 14.05.2020

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 3900 MHz; Type: D3900V2; Serial: D3900V2 - SN:1048

Communication System: UID 0 - CW; Frequency: 3900 MHz, Frequency: 4100 MHz

Medium parameters used: $f = 3900$ MHz; $\sigma = 3.21$ S/m; $\epsilon_r = 36.4$; $\rho = 1000$ kg/m³,

Medium parameters used: $f = 4100$ MHz; $\sigma = 3.39$ S/m; $\epsilon_r = 36.2$; $\rho = 1000$ kg/m³

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(7.39, 7.39, 7.39) @ 3900 MHz, ConvF(7.26, 7.26, 7.26) @ 4100 MHz; Calibrated: 31.12.2019
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 27.12.2019
- Phantom: Flat Phantom 5.0 (front); Type: QD 000 P50 AA; Serial: 1001
- DASY52 52.10.4(1527); SEMCAD X 14.6.14(7483)

Dipole Calibration for Head Tissue/Pin=100 mW, d=10mm, f=3900MHz/Zoom Scan,

dist=1.4mm (8x8x8)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 73.46 V/m; Power Drift = -0.02 dB

Peak SAR (extrapolated) = 20.2 W/kg

SAR(1 g) = 7.03 W/kg; SAR(10 g) = 2.45 W/kg

Smallest distance from peaks to all points 3 dB below = 7.9 mm

Ratio of SAR at M2 to SAR at M1 = 73.5%

Maximum value of SAR (measured) = 13.8 W/kg

Dipole Calibration for Head Tissue/Pin=100 mW, d=10mm, f=4100MHz/Zoom Scan,

dist=1.4mm (8x8x8)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 71.71 V/m; Power Drift = -0.02 dB

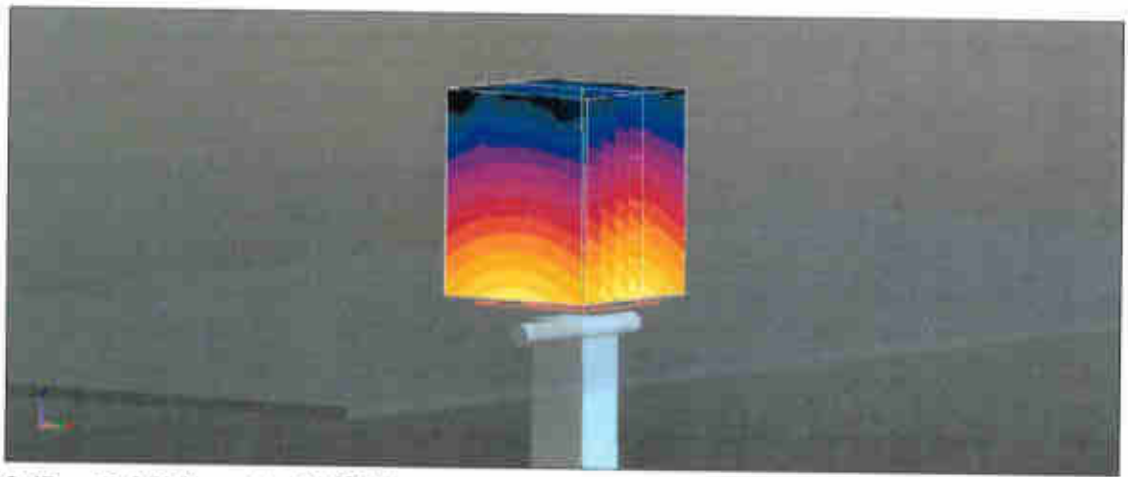
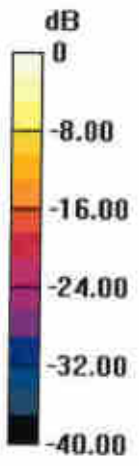
Peak SAR (extrapolated) = 19.8 W/kg

SAR(1 g) = 6.89 W/kg; SAR(10 g) = 2.39 W/kg

Smallest distance from peaks to all points 3 dB below = 8 mm

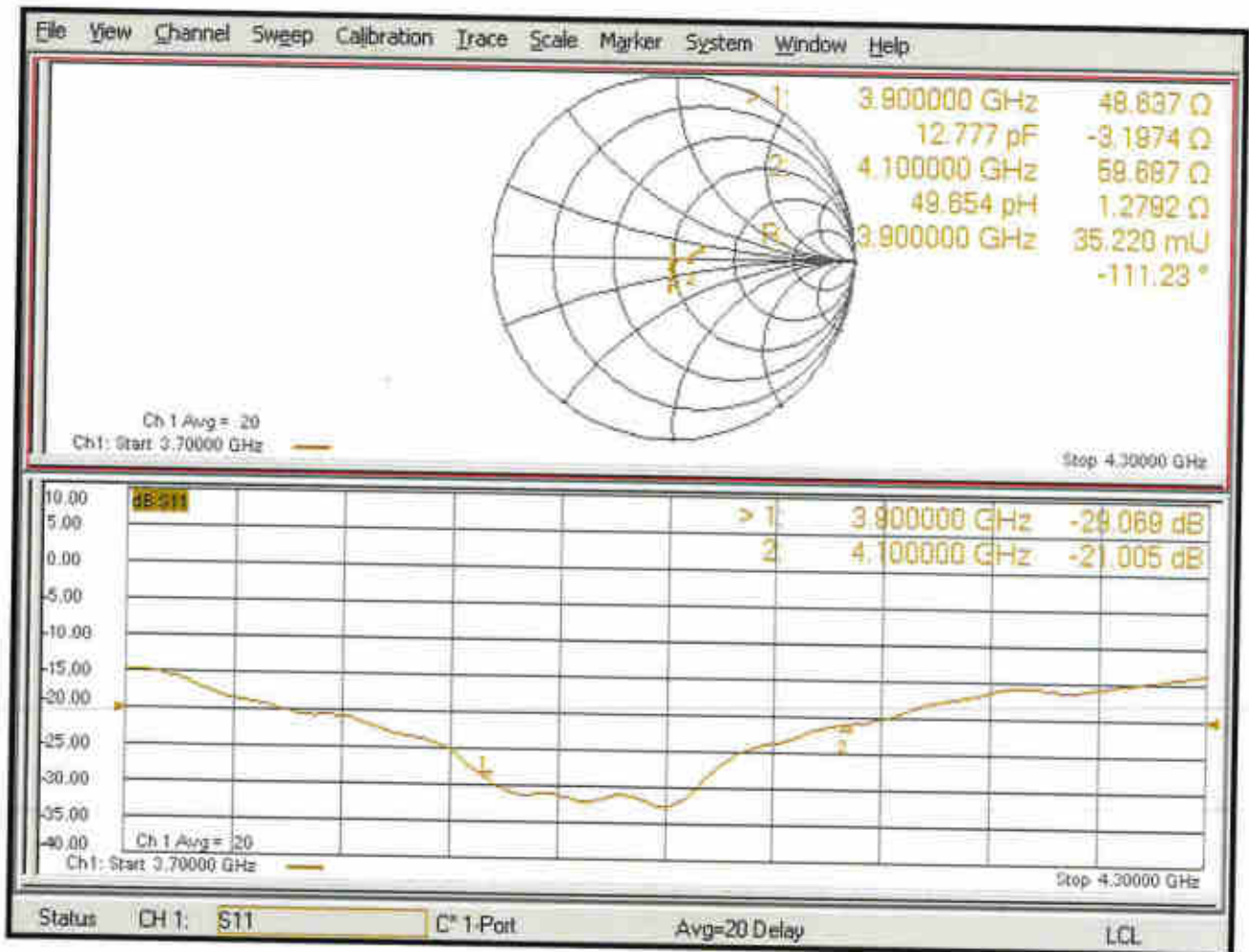
Ratio of SAR at M2 to SAR at M1 = 73.3%

Maximum value of SAR (measured) = 13.8 W/kg



0 dB = 13.8 W/kg = 11.40 dBW/kg

Impedance Measurement Plot for Head TSL





D3900V2, Serial No. 1048 Extended Dipole Calibrations

Referring to KDB 865664 D01 v01r04, if dipoles are verified in return loss ($< -20\text{dB}$, within 20% of prior calibration), and in impedance (within 5 ohm of prior calibration), the annual calibration is not necessary and the calibration interval can be extended.

D3900V2 – serial no. 1048						
3900 Head						
Date of Measurement	Return-Loss (dB)	Delta (%)	Real Impedance (ohm)	Delta (ohm)	Imaginary Impedance (ohm)	Delta (ohm)
2020.5.14	-29.069		48.637		-3.1974	
2021.5.13	-30.03	-0.03	51.501	-2.86	-2.8249	-0.37

D3900V2 – serial no. 1048						
4100 Head						
Date of Measurement	Return-Loss (dB)	Delta (%)	Real Impedance (ohm)	Delta (ohm)	Imaginary Impedance (ohm)	Delta (ohm)
2020.5.14	-21.005		59.687		1.2792	
2021.5.13	-22.284	-0.06	58.278	1.41	0.8744	0.40

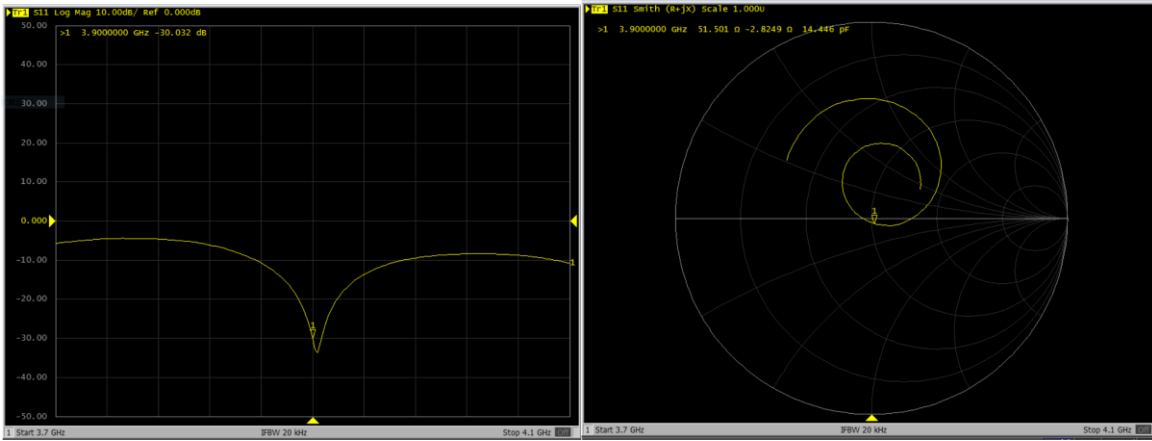
<Justification of the extended calibration>

The return loss is $< -20\text{dB}$, within 20% of prior calibration; the impedance is within 5 ohm of prior calibration. Therefore the verification result should support extended calibration.

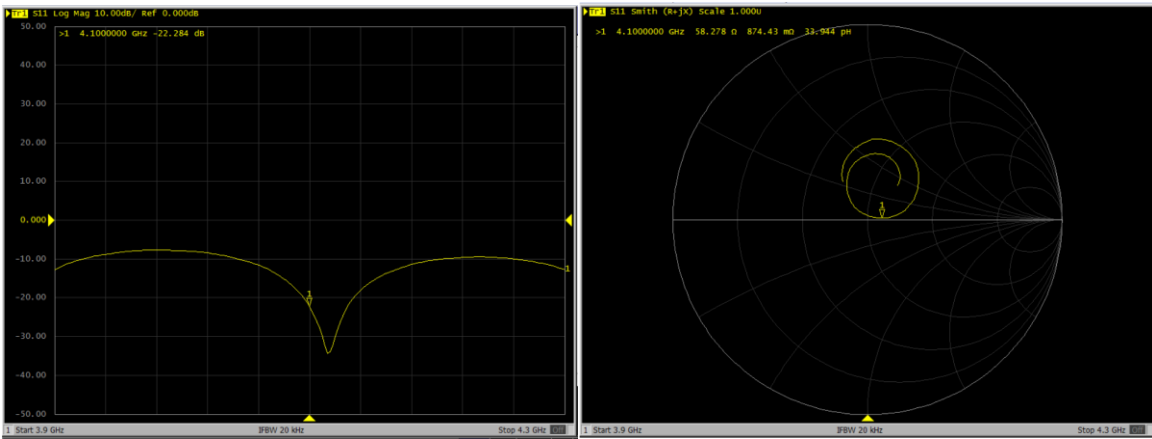


Dipole Verification Data> D3900V2, serial no. 1048

3900MHz – Head



4100MHz – Head





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Accreditation No.: **SCS 0108**

Client **Sporton**

Certificate No: **DAE4-1338_Nov20**

CALIBRATION CERTIFICATE

Object **DAE4 - SD 000 D04 BM - SN: 1338**

Calibration procedure(s) **QA CAL-06.v30
Calibration procedure for the data acquisition electronics (DAE)**

Calibration date: **November 27, 2020**

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 $(22 \pm 3)^\circ\text{C}$ and humidity $< 70\%$.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration
Kelthley Multimeter Type 2001	SN: 0810278	07-Sep-20 (No:28647)	Sep-21
Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Auto DAE Calibration Unit	SE UWS 053 AA 1001	09-Jan-20 (in house check)	In house check: Jan-21
Calibrator Box V2.1	SE UMS 006 AA 1002	09-Jan-20 (in house check)	In house check: Jan-21

Calibrated by: **Name** Adrian Gehring **Function** Laboratory Technician

Approved by: **Name** Sven Kühn **Function** Deputy Manager

Signature

Issued: November 27, 2020

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Accreditation No.: **SCS 0108**

Glossary

DAE data acquisition electronics
Connector angle information used in DASY system to align probe sensor X to the robot coordinate system.

Methods Applied and Interpretation of Parameters

- **DC Voltage Measurement:** Calibration Factor assessed for use in DASY system by comparison with a calibrated instrument traceable to national standards. The figure given corresponds to the full scale range of the voltmeter in the respective range.
- **Connector angle:** The angle of the connector is assessed measuring the angle mechanically by a tool inserted. Uncertainty is not required.
- The following parameters as documented in the Appendix contain technical information as a result from the performance test and require no uncertainty.
 - **DC Voltage Measurement Linearity:** Verification of the Linearity at +10% and -10% of the nominal calibration voltage. Influence of offset voltage is included in this measurement.
 - **Common mode sensitivity:** Influence of a positive or negative common mode voltage on the differential measurement.
 - **Channel separation:** Influence of a voltage on the neighbor channels not subject to an input voltage.
 - **AD Converter Values with inputs shorted:** Values on the internal AD converter corresponding to zero input voltage
 - **Input Offset Measurement:** Output voltage and statistical results over a large number of zero voltage measurements.
 - **Input Offset Current:** Typical value for information; Maximum channel input offset current, not considering the input resistance.
 - **Input resistance:** Typical value for information: DAE input resistance at the connector, during internal auto-zeroing and during measurement.
 - **Low Battery Alarm Voltage:** Typical value for information. Below this voltage, a battery alarm signal is generated.
 - **Power consumption:** Typical value for information. Supply currents in various operating modes.

DC Voltage Measurement

A/D - Converter Resolution nominal

High Range: 1LSB = 6.1 μ V, full range = -100...+300 mV

Low Range: 1LSB = 61nV, full range = -1.....+3mV

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

Calibration Factors	X	Y	Z
High Range	403.683 \pm 0.02% (k=2)	404.259 \pm 0.02% (k=2)	404.216 \pm 0.02% (k=2)
Low Range	3.97329 \pm 1.50% (k=2)	3.97760 \pm 1.50% (k=2)	3.97480 \pm 1.50% (k=2)

Connector Angle

Connector Angle to be used in DASY system	240.0 $^{\circ}$ \pm 1 $^{\circ}$
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Appendix (Additional assessments outside the scope of SCS0108)

1. DC Voltage Linearity

High Range	Reading (μV)	Difference (μV)	Error (%)
Channel X + Input	199991.64	-0.32	-0.00
Channel X + Input	20002.84	1.10	0.01
Channel X - Input	-20001.18	0.25	-0.00
Channel Y + Input	199992.25	0.36	0.00
Channel Y + Input	19999.51	-1.97	-0.01
Channel Y - Input	-20003.41	-1.82	0.01
Channel Z + Input	199993.13	0.96	0.00
Channel Z + Input	20000.60	-0.92	-0.00
Channel Z - Input	-20003.21	-1.57	0.01

Low Range	Reading (μV)	Difference (μV)	Error (%)
Channel X + Input	2001.46	0.54	0.03
Channel X + Input	201.63	0.29	0.14
Channel X - Input	-198.25	0.29	-0.15
Channel Y + Input	2001.07	0.18	0.01
Channel Y + Input	200.68	-0.49	-0.24
Channel Y - Input	-199.20	-0.52	0.26
Channel Z + Input	2000.41	-0.51	-0.03
Channel Z + Input	199.93	-1.28	-0.64
Channel Z - Input	-199.77	-1.08	0.54

2. Common mode sensitivity

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

	Common mode Input Voltage (mV)	High Range Average Reading (μV)	Low Range Average Reading (μV)
Channel X	200	7.08	5.84
	- 200	-6.14	-7.41
Channel Y	200	-21.12	-21.17
	- 200	20.10	20.00
Channel Z	200	-3.05	-2.98
	- 200	0.35	0.59

3. Channel separation

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

	Input Voltage (mV)	Channel X (μV)	Channel Y (μV)	Channel Z (μV)
Channel X	200	-	3.84	-3.07
Channel Y	200	8.29	-	4.87
Channel Z	200	8.97	6.36	-

4. AD-Converter Values with inputs shorted

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

	High Range (LSB)	Low Range (LSB)
Channel X	16191	14008
Channel Y	16286	16249
Channel Z	16106	15261

5. Input Offset Measurement

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

Input 10M Ω

	Average (μ V)	min. Offset (μ V)	max. Offset (μ V)	Std. Deviation (μ V)
Channel X	0.57	-0.12	1.34	0.31
Channel Y	-0.39	-0.99	0.23	0.27
Channel Z	-0.35	-1.05	0.40	0.28

6. Input Offset Current

Nominal Input circuitry offset current on all channels: <25fA

7. Input Resistance (Typical values for information)

	Zeroing (kOhm)	Measuring (MOhm)
Channel X	200	200
Channel Y	200	200
Channel Z	200	200

8. Low Battery Alarm Voltage (Typical values for information)

Typical values	Alarm Level (VDC)
Supply (+ Vcc)	+7.9
Supply (- Vcc)	-7.6

9. Power Consumption (Typical values for information)

Typical values	Switched off (mA)	Stand by (mA)	Transmitting (mA)
Supply (+ Vcc)	+0.01	+6	+14
Supply (- Vcc)	-0.01	-8	-9



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Accreditation No.: **SCS 0108**

Client **Sporton**

Certificate No: **EX3-3857_Sep20**

CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:3857**

Calibration procedure(s) **QA CAL-01.v9, QA CAL-14.v6, QA CAL-23.v5, QA CAL-25.v7
Calibration procedure for dosimetric E-field probes**

Calibration date: **September 25, 2020**

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	01-Apr-20 (No. 217-03100/03101)	Apr-21
Power sensor NRP-Z91	SN: 103244	01-Apr-20 (No. 217-03100)	Apr-21
Power sensor NRP-Z91	SN: 103245	01-Apr-20 (No. 217-03101)	Apr-21
Reference 20 dB Attenuator	SN: CC2552 (20x)	31-Mar-20 (No. 217-03106)	Apr-21
DAE4	SN: 660	27-Dec-19 (No. DAE4-660_Dec19)	Dec-20
Reference Probe ES3DV2	SN: 3013	31-Dec-19 (No. ES3-3013_Dec19)	Dec-20
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-20)	In house check: Jun-22
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-19)	In house check: Oct-20

Calibrated by:	Name Leif Klysner	Function Laboratory Technician	Signature
Approved by:	Name Katja Pokovic	Function Technical Manager	Signature
This calibration certificate shall not be reproduced except in full without written approval of the laboratory.			Issued: September 30, 2020



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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
NORM _{x,y,z}	sensitivity in free space
ConvF	sensitivity in TSL / NORM _{x,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., $\vartheta = 0$ 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:

- 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
- 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
- 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
- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Methods Applied and Interpretation of Parameters:

- NORM_{x,y,z}**: Assessed for E-field polarization $\vartheta = 0$ ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide). NORM_{x,y,z} are only intermediate values, i.e., the uncertainties of NORM_{x,y,z} does not affect the E²-field uncertainty inside TSL (see below ConvF).
- NORM(f)_{x,y,z}** = NORM_{x,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.
- DCP_{x,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
- A_{x,y,z}; B_{x,y,z}; C_{x,y,z}; D_{x,y,z}; VR_{x,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 $f \leq 800$ 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 NORM_{x,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 NORM_x (no uncertainty required).

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3857

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A	0.18	0.43	0.46	$\pm 10.1 \%$
DCP (mV) ^B	99.3	100.5	102.2	

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB $\sqrt{\mu\text{V}}$	C	D dB	VR mV	Max dev.	Unc ^E (k=2)
0	CW	X	0.0	0.0	1.0	0.00	182.0	$\pm 3.0 \%$	$\pm 4.7 \%$
		Y	0.0	0.0	1.0		178.6		
		Z	0.0	0.0	1.0		188.1		

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 Page 5).

^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.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3857

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	-118.9
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	337 mm
Probe Body Diameter	10 mm
Tip Length	9 mm
Tip Diameter	2.5 mm
Probe Tip to Sensor X Calibration Point	1 mm
Probe Tip to Sensor Y Calibration Point	1 mm
Probe Tip to Sensor Z Calibration Point	1 mm
Recommended Measurement Distance from Surface	1.4 mm

Note: Measurement distance from surface can be increased to 3-4 mm for an *Area Scan* job.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3857

Calibration Parameter Determined in Head Tissue Simulating Media

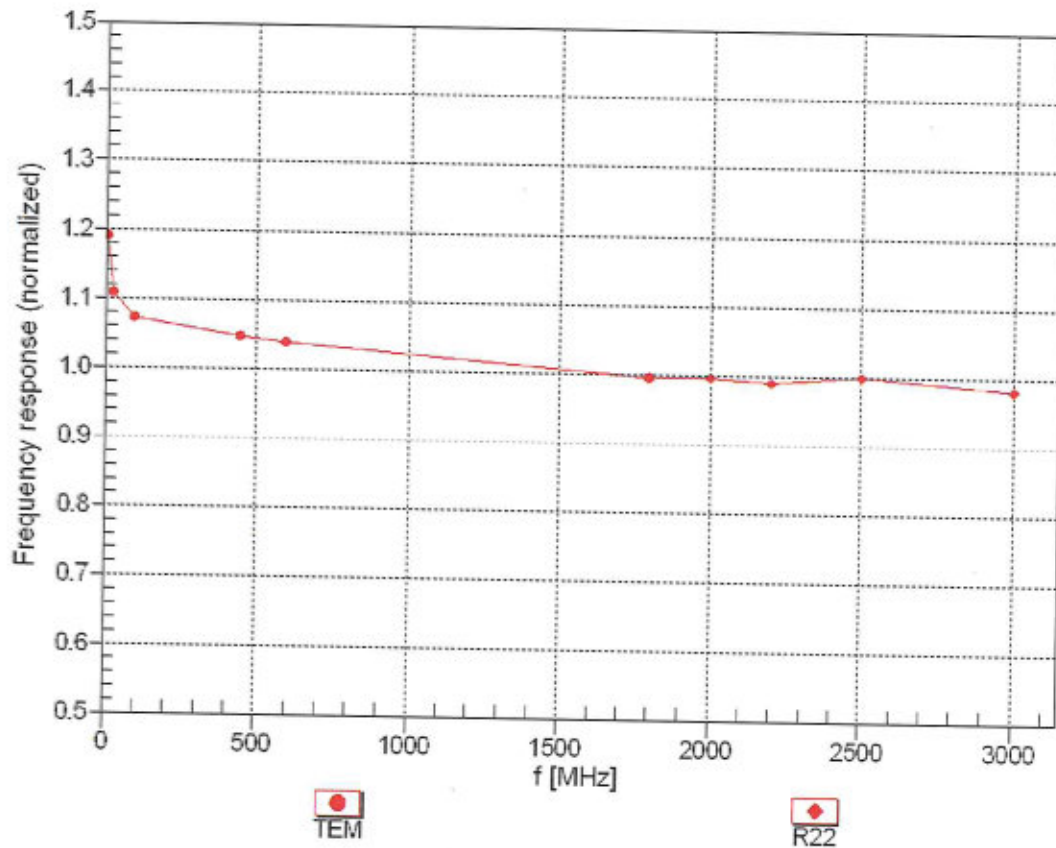
f (MHz) ^C	Relative Permittivity ^F	Conductivity (S/m) ^F	ConvF X	ConvF Y	ConvF Z	Alpha ^G	Depth (mm) ^G	Unc (k=2)
750	41.9	0.89	9.50	9.50	9.50	0.32	0.99	± 12.0 %
835	41.5	0.90	9.18	9.18	9.18	0.45	0.80	± 12.0 %
900	41.5	0.97	9.10	9.10	9.10	0.47	0.80	± 12.0 %
1750	40.1	1.37	8.06	8.06	8.06	0.27	0.86	± 12.0 %
1900	40.0	1.40	7.81	7.81	7.81	0.37	0.86	± 12.0 %
2000	40.0	1.40	7.78	7.78	7.78	0.40	0.86	± 12.0 %
2300	39.5	1.67	7.56	7.56	7.56	0.31	0.92	± 12.0 %
2450	39.2	1.80	7.44	7.44	7.44	0.40	0.92	± 12.0 %
2600	39.0	1.96	7.19	7.19	7.19	0.37	0.92	± 12.0 %
3300	38.2	2.71	6.70	6.70	6.70	0.30	1.35	± 14.0 %
3500	37.9	2.91	6.67	6.67	6.67	0.30	1.35	± 14.0 %
3700	37.7	3.12	6.61	6.61	6.61	0.30	1.35	± 14.0 %
3900	37.5	3.32	6.58	6.58	6.58	0.40	1.50	± 14.0 %
4100	37.2	3.53	6.08	6.08	6.08	0.35	1.50	± 14.0 %
4200	37.1	3.63	5.99	5.99	5.99	0.35	1.50	± 14.0 %
4400	36.9	3.84	5.93	5.93	5.93	0.35	1.70	± 14.0 %
4600	36.7	4.04	5.91	5.91	5.91	0.40	1.70	± 14.0 %
4800	36.4	4.25	5.76	5.76	5.76	0.40	1.80	± 14.0 %
4950	36.3	4.40	5.45	5.45	5.45	0.40	1.80	± 14.0 %
5250	35.9	4.71	5.04	5.04	5.04	0.40	1.80	± 14.0 %
5600	35.5	5.07	4.67	4.67	4.67	0.40	1.80	± 14.0 %
5750	35.4	5.22	4.93	4.93	4.93	0.40	1.80	± 14.0 %

^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. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.

^F At frequencies up to 6 GHz, the validity of tissue parameters (ϵ and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. 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)

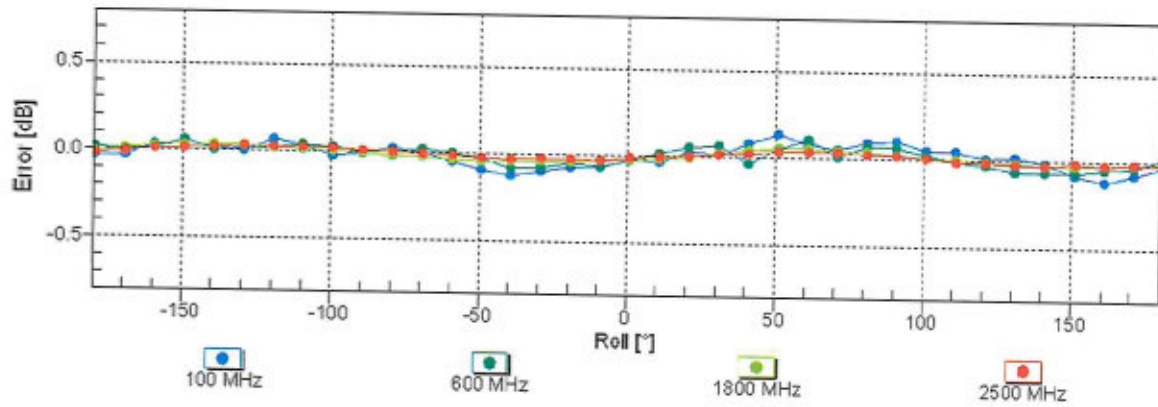
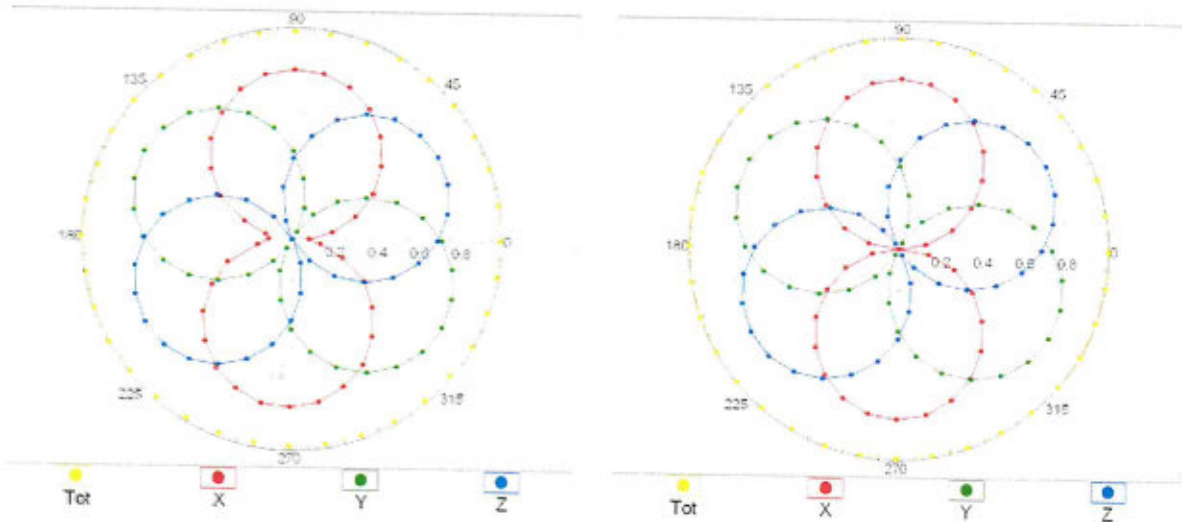


Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ (k=2)

Receiving Pattern (ϕ), $\theta = 0^\circ$

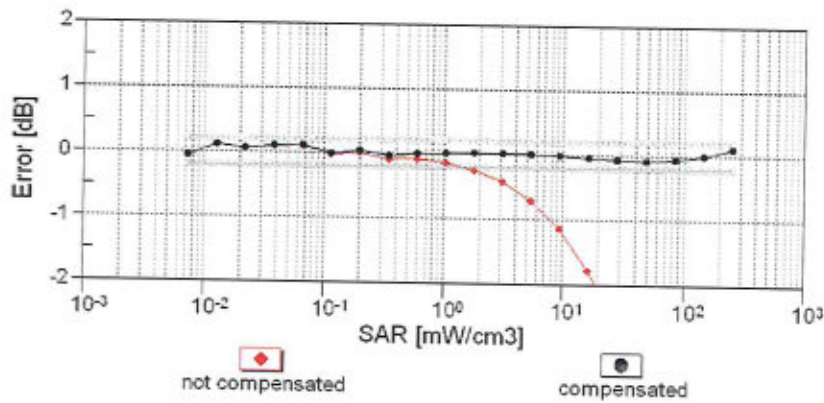
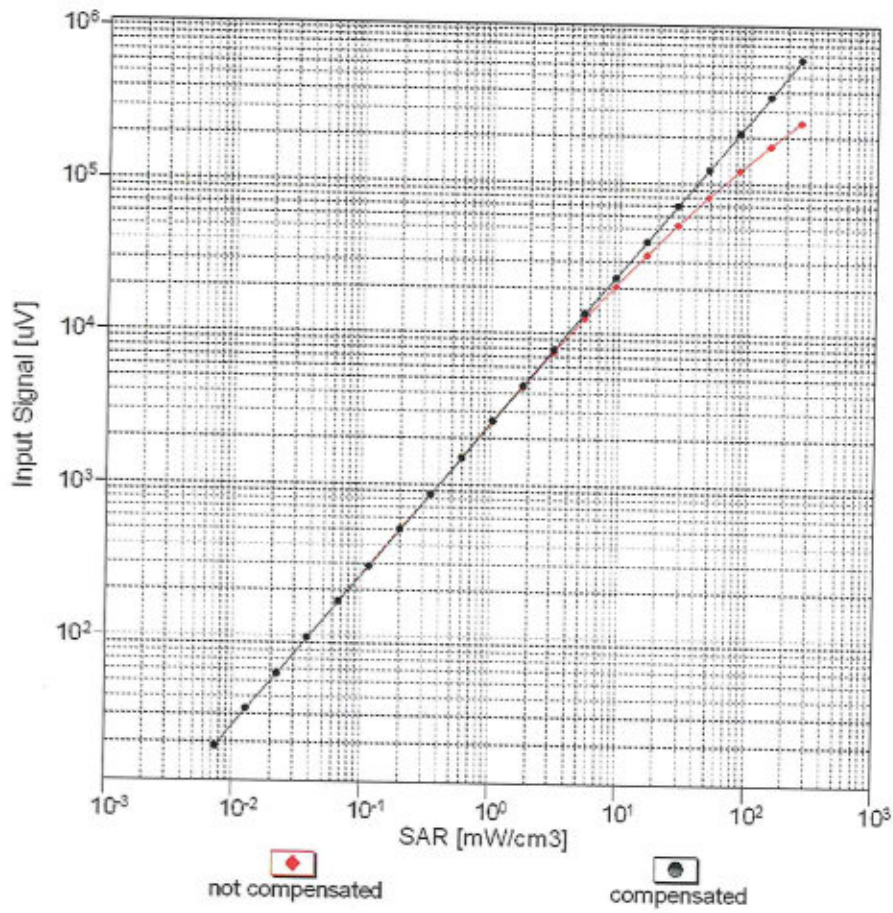
f=600 MHz,TEM

f=1800 MHz,R22



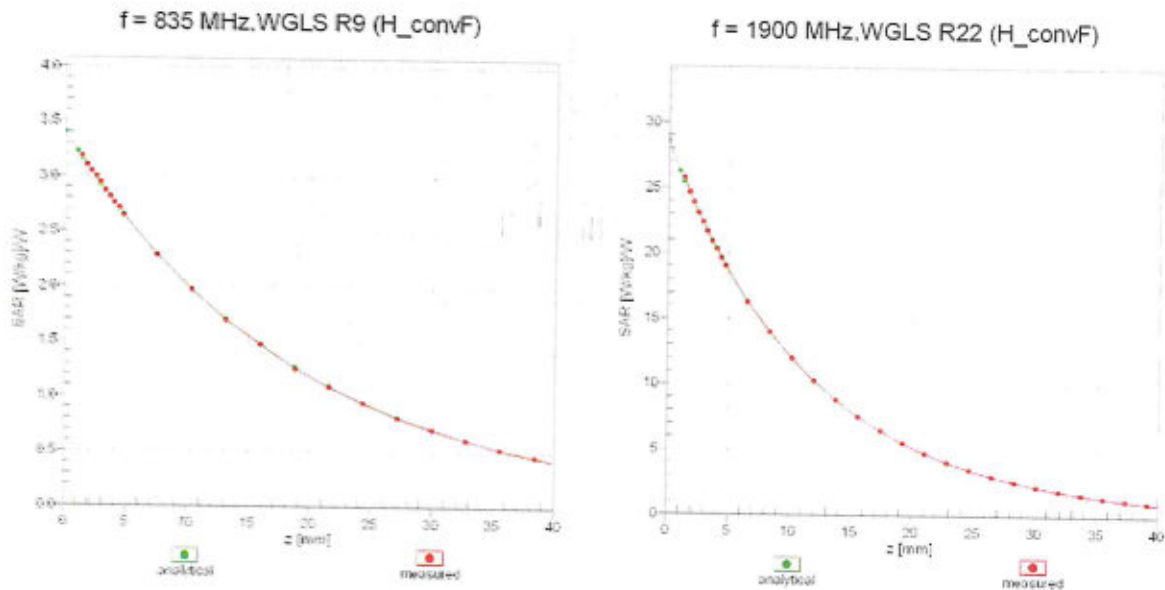
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

Dynamic Range $f(SAR_{head})$ (TEM cell , $f_{eval} = 1900$ MHz)

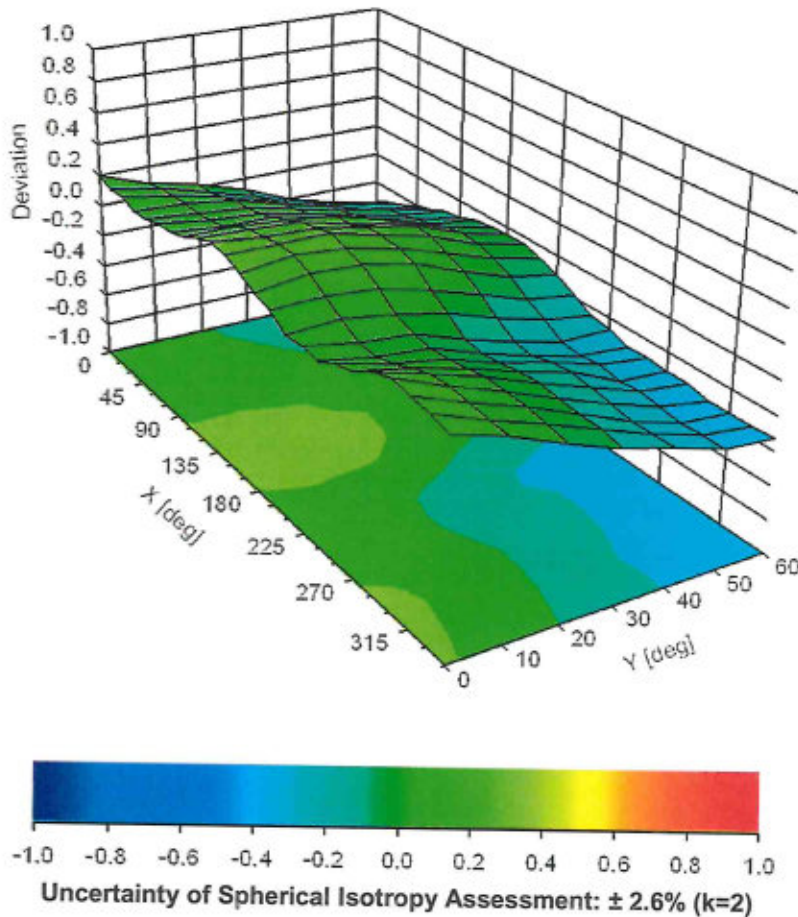


Uncertainty of Linearity Assessment: $\pm 0.6\%$ ($k=2$)

Conversion Factor Assessment



Deviation from Isotropy in Liquid Error (ϕ, θ), f = 900 MHz





Appendix E. Conducted RF Output Power Table

The detailed power tables are shown as follows.



n77_FCC_DFT-30									
BW [MHz]	Modulation	RB Size	RB Offset	Power Low Ch. / Freq.	Power Middle Ch. / Freq.	Power High Ch. / Freq.	Tune-up limit (dBm)	MPR (dB)	
Channel									
Frequency (MHz)									
100	PI2 BPSK	1	1	22.20	22.28	22.17			
100	PI2 BPSK	1	137	22.91	23.09	22.96	24.0	0.0	
100	PI2 BPSK	1	271	22.81	22.82	22.85			
100	PI2 BPSK	135	0	22.35	22.41	22.39	23.5	0.5	
100	PI2 BPSK	135	69	22.20	22.34	22.24	24.0	0.0	
100	PI2 BPSK	135	138	23.04	23.14	23.01			
100	PI2 BPSK	270	0	22.81	22.99	22.94	23.5	0.5	
100	QPSK	1	1	23.06	23.18	23.15			
100	QPSK	1	137	22.94	23.03	22.99	24.0	0.0	
100	QPSK	1	271	22.68	22.82	22.66			
100	QPSK	135	0	22.12	22.17	22.02	23.0	1.0	
100	QPSK	135	69	22.98	23.12	22.99	24.0	0.0	
100	QPSK	135	138	22.91	22.78	22.94			
100	QPSK	270	0	22.80	22.83	22.81	23.0	1.0	
100	16QAM	1	1	21.85	22.02	22.00	22.5	1.5	
100	64QAM	1	1	21.88	21.99	21.91	22.5	1.5	
100	256QAM	1	1	21.01	21.08	21.11	22.0	2.0	
Channel									
Frequency (MHz)									
80	QPSK	1	1	3740.01	3840	3840.02	Tune-up limit (dBm)	MPR (dB)	
Channel									
Frequency (MHz)									
60	QPSK	1	1	22.57	22.82	22.69	24.0	0.0	
Channel									
Frequency (MHz)									
50	QPSK	1	1	22.73	22.84	22.71	24.0	0.0	
Channel									
Frequency (MHz)									
40	QPSK	1	1	22.58	22.87	22.79	24.0	0.0	
Channel									
Frequency (MHz)									
20	QPSK	1	1	22.84	22.70	22.68	24.0	0.0	
Channel									
Frequency (MHz)									
15	QPSK	1	1	22.65	22.73	22.67	24.0	0.0	
Channel									
Frequency (MHz)									
10	QPSK	1	1	22.65	22.69	22.61	24.0	0.0	

n78_FCC_DFT-30									
BW [MHz]	Modulation	RB Size	RB Offset	Power Low Ch. / Freq.	Power Middle Ch. / Freq.	Power High Ch. / Freq.	Tune-up limit (dBm)	MPR (dB)	
Channel									
Frequency (MHz)									
100	PI2 BPSK	1	1	22.43					
100	PI2 BPSK	1	137	22.91			24.0	0.0	
100	PI2 BPSK	1	271	22.13					
100	PI2 BPSK	135	0	22.87			23.5	0.5	
100	PI2 BPSK	135	69	22.91			24.0	0.0	
100	PI2 BPSK	135	138	22.97					
100	PI2 BPSK	270	0	22.93			23.5	0.5	
100	QPSK	1	1	23.12					
100	QPSK	1	137	23.03			24.0	0.0	
100	QPSK	1	271	22.16					
100	QPSK	135	0	22.75			23.5	0.5	
100	QPSK	135	69	23.11			24.0	0.0	
100	QPSK	135	138	22.14					
100	QPSK	270	0	22.29			23.5	0.5	
100	16QAM	1	1	22.20			22.5	1.5	
100	64QAM	1	1	22.26			22.5	1.5	
100	256QAM	1	1	21.24			22.0	2.0	
Channel									
Frequency (MHz)									
80	QPSK	1	1	3740.01	3760	3760.02	Tune-up limit (dBm)	MPR (dB)	
Channel									
Frequency (MHz)									
60	QPSK	1	1	22.27	22.38	22.37	24.0	0.0	
Channel									
Frequency (MHz)									
50	QPSK	1	1	22.24	22.48	22.38	24.0	0.0	
Channel									
Frequency (MHz)									
40	QPSK	1	1	22.34	22.41	22.32	24.0	0.0	
Channel									
Frequency (MHz)									
20	QPSK	1	1	22.41	22.50	22.37	24.0	0.0	
Channel									
Frequency (MHz)									
15	QPSK	1	1	22.30	22.41	22.37	24.0	0.0	
Channel									
Frequency (MHz)									
10	QPSK	1	1	22.26	22.57	22.29	24.0	0.0	

n78_FCC_HPUE_DFT-30									
BW [MHz]	Modulation	RB Size	RB Offset	Power Low Ch. / Freq.	Power Middle Ch. / Freq.	Power High Ch. / Freq.	Tune-up limit (dBm)	MPR (dB)	
Channel									
Frequency (MHz)									
100	PI2 BPSK	1	1	23.97					
100	PI2 BPSK	1	137	24.31			28.0	0.0	
100	PI2 BPSK	1	271	24.31					
100	PI2 BPSK	135	0	24.45			25.5	0.5	
100	PI2 BPSK	135	69	24.37			26.0	0.0	
100	PI2 BPSK	135	138	24.59					
100	PI2 BPSK	270	0	24.49			25.5	0.5	
100	QPSK	1	1	24.96					
100	QPSK	1	137	24.59			26.0	0.0	
100	QPSK	1	271	26.29					
100	QPSK	135	0	23.91			25.0	1.0	
100	QPSK	135	69	24.94			26.0	0.0	
100	QPSK	135	138	24.03					
100	QPSK	270	0	26.13			25.0	1.0	
100	16QAM	1	1	23.16			25.0	1.0	
100	64QAM	1	1	21.82			23.5	2.5	
100	256QAM	1	1	20.30			21.5	4.5	
Channel									
Frequency (MHz)									
80	QPSK	1	1	3740.01	3760	3760.02	Tune-up limit (dBm)	MPR (dB)	
Channel									
Frequency (MHz)									
60	QPSK	1	1	24.34	24.36	24.37	26.0	0.0	
Channel									
Frequency (MHz)									
50	QPSK	1	1	24.29	24.29	24.29	26.0	0.0	
Channel									
Frequency (MHz)									
40	QPSK	1	1	24.38	24.27	24.37	26.0	0.0	
Channel									
Frequency (MHz)									
20	QPSK	1	1	24.37	24.27	24.33	26.0	0.0	
Channel									
Frequency (MHz)									
15	QPSK	1	1	24.37	24.19	24.29	26.0	0.0	
Channel									
Frequency (MHz)									
10	QPSK	1	1	24.42	24.33	24.23	26.0	0.0	



n77_FCC_DFT-15									
BW (MHz)	Modulation	RB Size	RB Offset	Power Low Ch. Freq.	Power Middle Ch. Freq.	Power High Ch. Freq.	Tune-up limit (dBm)	MPR (dB)	
Channel				647334	650000	666668			
Frequency (MHz)				3710.01	3840	3710.02			
20	Pi/2 BPSK	1	1	22.14	22.29	22.15	24.0	0.0	
20	Pi/2 BPSK	1	53	22.82	23.09	22.79			
20	Pi/2 BPSK	1	104	22.70	22.65	22.59			
20	Pi/2 BPSK	50	0	22.18	22.36	22.26	23.5	0.5	
20	Pi/2 BPSK	50	28	22.16	22.26	22.03	24.0	0.0	
20	Pi/2 BPSK	50	56	22.92	23.06	22.83			
20	Pi/2 BPSK	100	0	22.70	22.96	22.76	23.5	0.5	
20	QPSK	1	1	22.86	23.17	22.98			
20	QPSK	1	53	22.92	23.02	22.85	24.0	0.0	
20	QPSK	1	104	22.56	22.79	22.55			
20	QPSK	50	0	22.11	21.94	21.89	23.0	1.0	
20	QPSK	50	28	22.87	22.92	22.86	24.0	0.0	
20	QPSK	50	56	22.75	22.70	22.65			
20	QPSK	100	0	22.58	22.68	22.64	23.0	1.0	
20	16QAM	1	1	21.75	21.89	21.82	22.5	1.5	
20	16QAM	1	1	21.80	21.86	21.85	22.5	1.5	
20	16QAM	1	1	20.90	20.90	21.10	22.0	2.0	
Channel				647168	650000	666834	Tune-up limit (dBm)	MPR	
Frequency (MHz)				3707.52	3840	3707.51	(dBm)	(dB)	
15	QPSK	1	1	22.15	23.03	22.81	24.0	0.0	
Channel				647000	650000	653000	Tune-up limit (dBm)	MPR	
Frequency (MHz)				3705	3840	3705	(dBm)	(dB)	
10	QPSK	1	1	22.70	23.08	22.81	24.0	0.0	

n78_FCC_DFT-15									
BW (MHz)	Modulation	RB Size	RB Offset	Power Low Ch. Freq.	Power Middle Ch. Freq.	Power High Ch. Freq.	Tune-up limit (dBm)	MPR (dB)	
Channel				647334	650000	666668			
Frequency (MHz)				3710.01	3750	3710.02			
20	Pi/2 BPSK	1	1	22.59	22.23	22.26	24.0	0.0	
20	Pi/2 BPSK	1	53	22.90	22.96	22.92			
20	Pi/2 BPSK	1	104	22.03	21.91	21.94			
20	Pi/2 BPSK	50	0	22.72	22.87	22.89	23.5	0.5	
20	Pi/2 BPSK	50	28	22.76	22.83	22.77	24.0	0.0	
20	Pi/2 BPSK	50	56	22.93	22.84	22.78			
20	Pi/2 BPSK	100	0	22.71	22.76	22.82	23.5	0.5	
20	QPSK	1	1	22.98	22.99	22.91			
20	QPSK	1	53	22.90	22.87	22.84	24.0	0.0	
20	QPSK	1	104	21.94	22.03	22.07			
20	QPSK	50	0	22.68	22.54	22.71	23.5	0.5	
20	QPSK	50	28	23.03	23.10	22.91	24.0	0.0	
20	QPSK	50	56	21.92	21.91	22.02			
20	QPSK	100	0	22.21	22.23	22.07	23.5	0.5	
20	16QAM	1	1	21.88	22.18	22.19	22.5	1.5	
20	16QAM	1	1	22.19	22.23	22.24	22.5	1.5	
20	16QAM	1	1	21.23	21.08	21.16	22.0	2.0	
Channel				647168	650000	666834	Tune-up limit (dBm)	MPR	
Frequency (MHz)				3707.52	3750	3707.51	(dBm)	(dB)	
15	QPSK	1	1	22.77	22.52	22.79	24.0	0.0	
Channel				647000	650000	653000	Tune-up limit (dBm)	MPR	
Frequency (MHz)				3705	3750	3705	(dBm)	(dB)	
10	QPSK	1	1	22.76	22.76	22.70	24.0	0.0	

n78_FCC_HPUE_DFT-15									
BW (MHz)	Modulation	RB Size	RB Offset	Power Low Ch. Freq.	Power Middle Ch. Freq.	Power High Ch. Freq.	Tune-up limit (dBm)	MPR (dB)	
Channel				647334	650000	666668			
Frequency (MHz)				3710.01	3750	3710.02			
20	Pi/2 BPSK	1	1	23.77	23.79	23.83			
20	Pi/2 BPSK	1	53	24.26	24.28	24.25	28.0	0.0	
20	Pi/2 BPSK	1	104	24.31	24.21	24.25			
20	Pi/2 BPSK	50	0	24.30	24.29	24.30	25.5	0.5	
20	Pi/2 BPSK	50	28	24.27	24.26	24.24	26.0	0.0	
20	Pi/2 BPSK	50	56	24.55	24.45	24.38			
20	Pi/2 BPSK	100	0	24.41	24.41	24.40	25.5	0.5	
20	QPSK	1	1	24.87	24.89	24.83			
20	QPSK	1	53	24.54	24.63	24.67	28.0	0.0	
20	QPSK	1	104	24.24	24.12	24.18			
20	QPSK	50	0	23.87	23.89	23.84	25.0	1.0	
20	QPSK	50	28	24.83	24.88	24.79	26.0	0.0	
20	QPSK	50	56	23.88	23.89	23.87			
20	QPSK	100	0	24.03	24.08	24.02	25.0	1.0	
20	16QAM	1	1	23.08	23.05	23.06	25.0	1.0	
20	16QAM	1	1	21.71	21.76	21.67	23.5	2.5	
20	16QAM	1	1	20.29	20.22	20.11	21.5	4.5	
Channel				647168	650000	666834	Tune-up limit (dBm)	MPR	
Frequency (MHz)				3707.52	3750	3707.51	(dBm)	(dB)	
15	QPSK	1	1	24.75	24.72	24.73	23.0	0.0	
Channel				647000	650000	653000	Tune-up limit (dBm)	MPR	
Frequency (MHz)				3705	3750	3705	(dBm)	(dB)	
10	QPSK	1	1	24.76	24.70	24.71	26.0	0.0	