Calibration Report for Antenna - Dipole

PsaCal
2020.06.10.0

DUT Code:	ADM	Cal Date:	2020-11-09
Description	Antenna - Dipole	Temperature:	20.4C
Model	D5GHzV2	Humidity:	37.80%
Manufacturer	SPEAG Tester: Kyle McMullan	Pressure:	1012.6mb
Certificate No.:	ADM2020-11-09	Job Site:	MN11

TEST SPECIFICATIONS

Specification:	WP 438 SAR Dipole Verificaiton	Version:	2020 - Rev 0
Specification:		Version:	

TEST PARAMETERS

Device Received In Tolerance:	Yes	Calibrated Frequency Range:	N/A	Next Cal Due Date:	2021-11-10

Equipment Used to perform calibration

Item:	Analyzer - Network Analyzer	Identifier:	NAM	Model:	E5071C	Last Cal:	2019-11-13	Cal Due:	2022-11-13
Item:	Fixture/Kit - Calibration/Verification	Identifier:	NAN	Model:	85032F	Last Cal:	NCR	Cal Due:	NCR
Item:	Terminator	Identifier:	NANA	Model:	85032-60017	Last Cal:	2020-09-10	Cal Due:	2021-09-10
Item:		Identifier:		Model:		Last Cal:		Cal Due:	
Item:		Identifier:		Model:		Last Cal:		Cal Due:	
Item:		Identifier:		Model:		Last Cal:		Cal Due:	

COMMENTS, OPINIONS and INTERPRETATIONS

None

Measurement Uncertainty

	Probability Distribution	Impedance (dB)	Insertion Loss (dB)	Value (dB)	Value (+/- %)
Expanded uncertainty U (level of confidence = 95%)	normal (k=2)			0.81	

RESULTS

Pass

This measurement was a calibration verification. (Instrument parameters are within tolerances.)

Measurements are traceable to the International System of Units (SI) via NIST.

CALIBRATION DATA ATTACHED

			Return Loss		Real Impedence	Imaginary Impedence
5200 MHz	Head Phantom	2020 Value (dB)	-23.7	2020 Value (Ω)	47.9	-6.0
		2019 Value (dB)	-22.6	2019 Value (Ω)	51.9	-7.3
		Deviation (%)	-4.9	Deviation (Ω)	4	-1.3
		Limit (%)	20	Limit (Ω)	5	5
		Limit (< dB)	-20	Results	Pass	Pass
		Results	Pass			
	Body Phantom	2020 Value (dB)	-25.8	2020 Value (Ω)	48.5	-3.9
		2019 Value (dB)	-23.6	2019 Value (Ω)	51.9	-6.4
		Deviation (%)	-9.3	Deviation (Ω)	3.4	-2.5
		Limit (%)	20	Limit (Ω)	5	5
		Limit (< dB)	-20	Results	Pass	Pass
		Results	Pass			

			Return Loss		Real Impedence	Imaginary Impedence
5300 MHz	Head Phantom	2020 Value (dB)	-32.1	2020 Value (Ω)	48.2	2.6
		2019 Value (dB)	-35.0	2019 Value (Ω)	50.4	-1.7
		Deviation (%)	8.3	Deviation (Ω)	2.2	-4.3
		Limit (%)	20	Limit (Ω)	5	5
		Limit (< dB)	-20	Results	Pass	Pass
		Results	Pass			
	Body Phantom	2020 Value (dB)	-34.0	2020 Value (Ω)	50.9	3.3
		2019 Value (dB)	-36.9	2019 Value (Ω)	50.6	-1.3
		Deviation (%)	7.9	Deviation (Ω)	-0.3	-4.6
		Limit (%)	20	Limit (Ω)	5	5
		Limit (< dB)	-20	Results	Pass	Pass
		Results	Pass			

			Return Loss		Real Impedence	Imaginary Impedence
5500 MHz	Head Phantom	2020 Value (dB)	-30.4	2020 Value (Ω)	53.1	0.0
		2019 Value (dB)	-32.4	2019 Value (Ω)	50.9	-2.2
		Deviation (%)	6.2	Deviation (Ω)	-2.2	-2.2
		Limit (%)	20	Limit (Ω)	5	5
		Limit (< dB)	-20	Results	Pass	Pass
		Results	Pass			
	Body Phantom	2020 Value (dB)	-29.0	2020 Value (Ω)	52.6	2.5
		2019 Value (dB)	-31.9	2019 Value (Ω)	52.0	-1.7
		Deviation (%)	9.1	Deviation (Ω)	-0.6	-4.2
		Limit (%)	20	Limit (Ω)	5	5
		Limit (< dB)	-20	Results	Pass	Pass
		Results	Pass			

			Return Loss		Real Impedence	Imaginary Impedence
5600 MHz	Head Phantom	2020 Value (dB)	-24.3	2020 Value (Ω)	52.4	-3.8
		2019 Value (dB)	-23.4	2019 Value (Ω)	57.2	-0.3
		Deviation (%)	-3.8	Deviation (Ω)	4.8	3.5
		Limit (%)	20	Limit (Ω)	5	5
		Limit (< dB)	-20	Results	Pass	Pass
		Results	Pass			
	Body Phantom	2020 Value (dB)	53.2	2020 Value (Ω)	53.2	-4.7
		2019 Value (dB)	-24.0	2019 Value (Ω)	56.7	-0.1
		Deviation (%)	321.7	Deviation (Ω)	3.5	4.6
		Limit (%)	20	Limit (Ω)	5	5
		Limit (< dB)	-20	Results	Pass	Pass
		Results	Pass			

			Return Loss		Real Impedence	Imaginary Impedence
5800 MHz	Head Phantom	2020 Value (dB)	-27.5	2020 Value (Ω)	52.1	2.8
		2019 Value (dB)	-25.2	2019 Value (Ω)	55.8	0.5
		Deviation (%)	-9.1	Deviation (Ω)	3.7	-2.3
		Limit (%)	20	Limit (Ω)	5	5
		Limit (< dB)	-20	Results	Pass	Pass
		Results	Pass			
	Body Phantom	2020 Value (dB)	-25.4	2020 Value (Ω)	51.4	4.6
		2019 Value (dB)	-25.0	2019 Value (Ω)	56	-0.1
		Deviation (%)	-1.6	Deviation (Ω)	4.6	-4.7
		Limit (%)	20	Limit (Ω)	5	5
		Limit (< dB)	-20	Results	Pass	Pass
		Results	Pass			

Calibration Laboratory of
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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

SAG

Client **Element**

Certificate No: EX3-3746_Nov20

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:3746
Calibration procedure(s)	QA CAL-01.v9, QA CAL-12.v9, QA CAL-14.v6, QA CAL-23.v5, QA CAL-25.v7 Calibration procedure for dosimetric E-field probes
Calibration date:	November 18, 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-20)	In house check: Oct-21

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

Issued: November 24, 2020

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).

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3746

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu V/(V/m)^2$)[A]	0.31	0.27	0.21	± 10.1 %
DCP (mV)[B]	102.6	96.7	102.2	

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB$\sqrt{\mu V}$	C	D dB	VR mV	Max dev.	Unc[E] (k=2)
0	CW	X	0.0	0.0	1.0	0.00	138.7	± 2.7 %	± 4.7 %
		Y	0.0	0.0	1.0		137.0		
		Z	0.0	0.0	1.0		154.4		

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.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3746

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	-114.6
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:3746

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	10.39	10.39	10.39	0.13	1.30	± 13.3 %
750	41.9	0.89	9.37	9.37	9.37	0.58	0.80	± 12.0 %
835	41.5	0.90	9.11	9.11	9.11	0.40	0.90	± 12.0 %
900	41.5	0.97	8.93	8.93	8.93	0.51	0.80	± 12.0 %
1750	40.1	1.37	8.03	8.03	8.03	0.25	0.86	± 12.0 %
1900	40.0	1.40	7.62	7.62	7.62	0.30	0.86	± 12.0 %
2300	39.5	1.67	7.48	7.48	7.48	0.30	0.86	± 12.0 %
2450	39.2	1.80	7.22	7.22	7.22	0.33	0.82	± 12.0 %
2550	39.1	1.91	6.94	6.94	6.94	0.26	0.86	± 12.0 %
3500	37.9	2.91	6.75	6.75	6.75	0.30	1.30	± 13.1 %
3700	37.7	3.12	6.68	6.68	6.68	0.35	1.30	± 13.1 %
5200	36.0	4.66	5.13	5.13	5.13	0.40	1.80	± 13.1 %
5300	35.9	4.76	4.99	4.99	4.99	0.40	1.80	± 13.1 %
5500	35.6	4.96	4.59	4.59	4.59	0.40	1.80	± 13.1 %
5600	35.5	5.07	4.48	4.48	4.48	0.40	1.80	± 13.1 %
5800	35.3	5.27	4.46	4.46	4.46	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. 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 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.

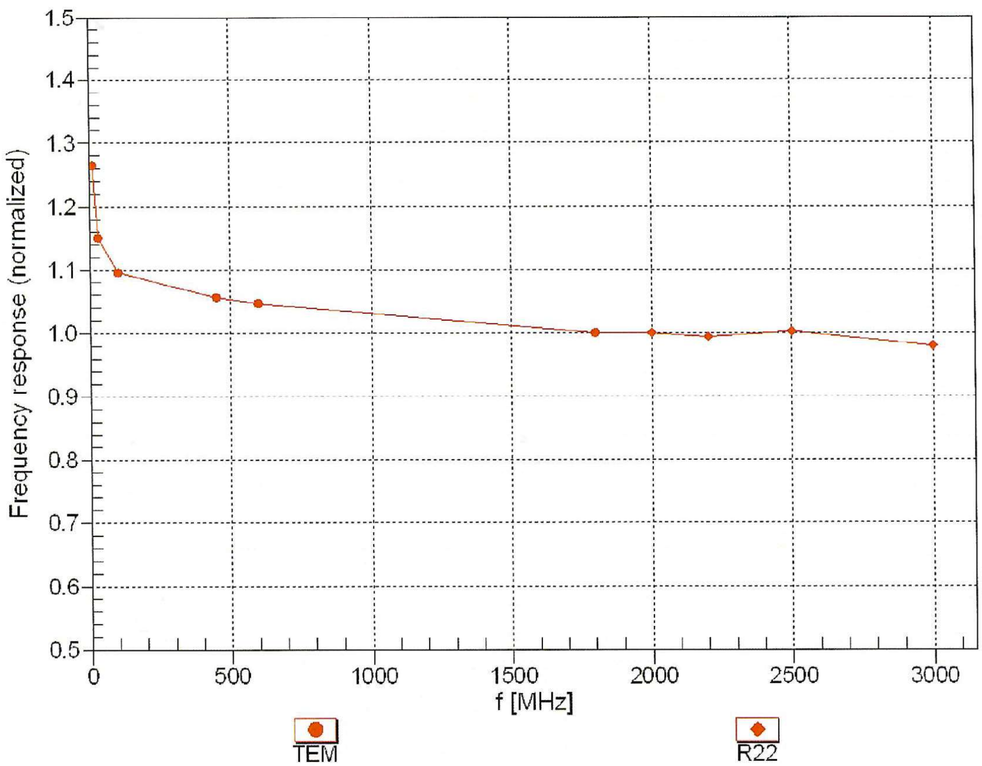
DASY/EASY - Parameters of Probe: EX3DV4 - SN:3746

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	10.41	10.41	10.41	0.08	1.20	± 13.3 %
750	55.5	0.96	9.35	9.35	9.35	0.39	0.80	± 12.0 %
835	55.2	0.97	9.08	9.08	9.08	0.40	0.89	± 12.0 %
900	55.0	1.05	9.01	9.01	9.01	0.37	0.80	± 12.0 %
1750	53.4	1.49	7.78	7.78	7.78	0.31	0.88	± 12.0 %
1900	53.3	1.52	7.50	7.50	7.50	0.41	0.80	± 12.0 %
2300	52.9	1.81	7.47	7.47	7.47	0.46	0.86	± 12.0 %
2450	52.7	1.95	7.35	7.35	7.35	0.38	0.80	± 12.0 %
2550	52.6	2.09	7.15	7.15	7.15	0.31	0.80	± 12.0 %
3500	51.3	3.31	6.50	6.50	6.50	0.40	1.30	± 13.1 %
3700	51.0	3.55	6.32	6.32	6.32	0.40	1.30	± 13.1 %
5200	49.0	5.30	4.31	4.31	4.31	0.50	1.90	± 13.1 %
5300	48.9	5.42	4.20	4.20	4.20	0.50	1.90	± 13.1 %
5500	48.6	5.65	3.83	3.83	3.83	0.50	1.90	± 13.1 %
5600	48.5	5.77	3.77	3.77	3.77	0.50	1.90	± 13.1 %
5800	48.2	6.00	3.75	3.75	3.75	0.50	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. 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 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.

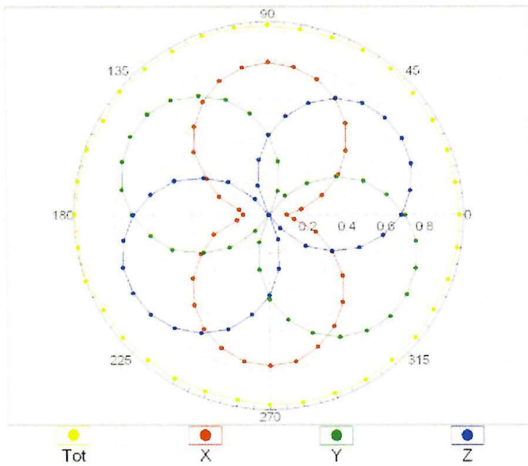
Frequency Response of E-Field
(TEM-Cell:ifi110 EXX, Waveguide: R22)



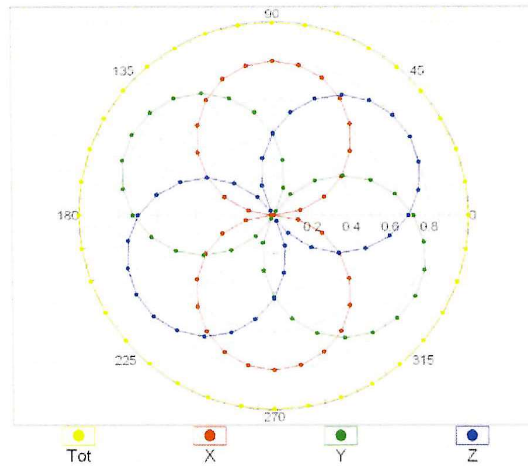
Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

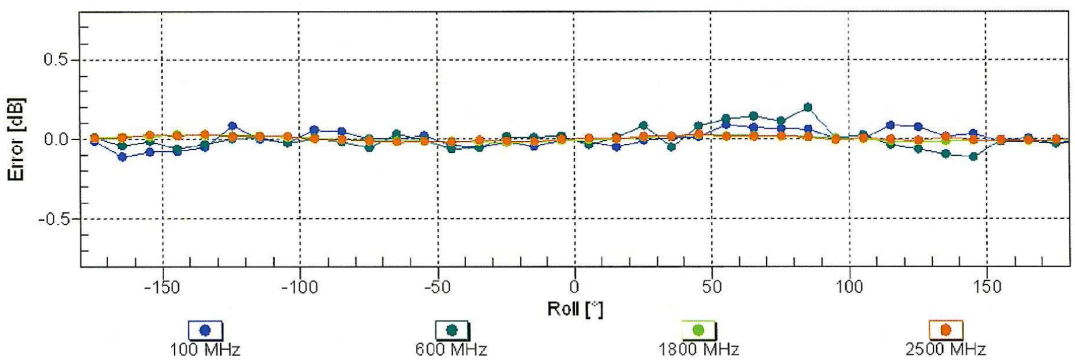
Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM



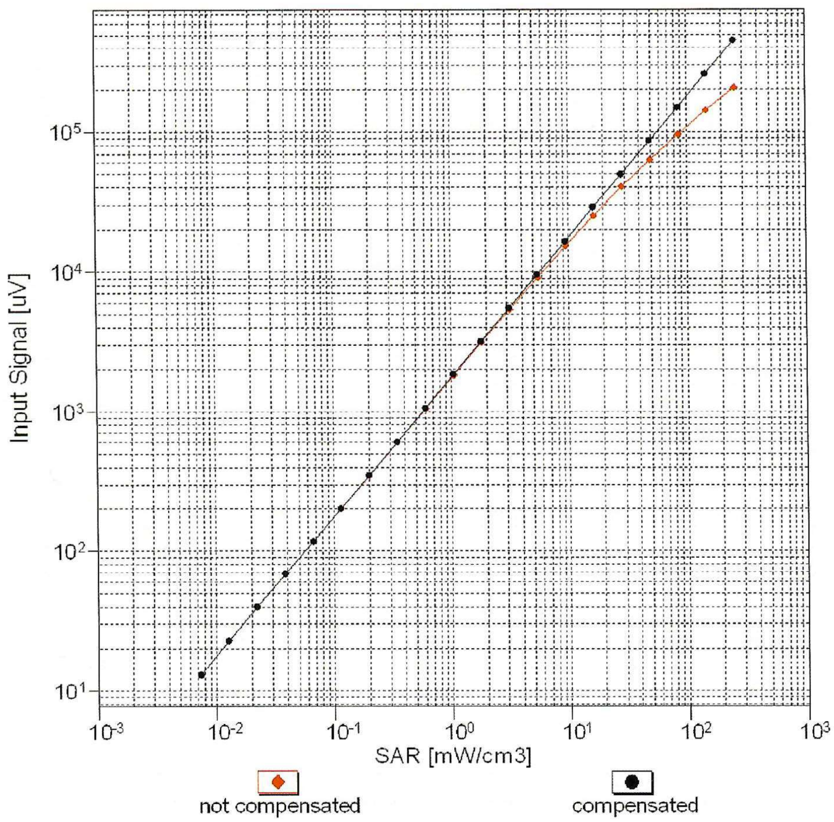
f=1800 MHz,R22

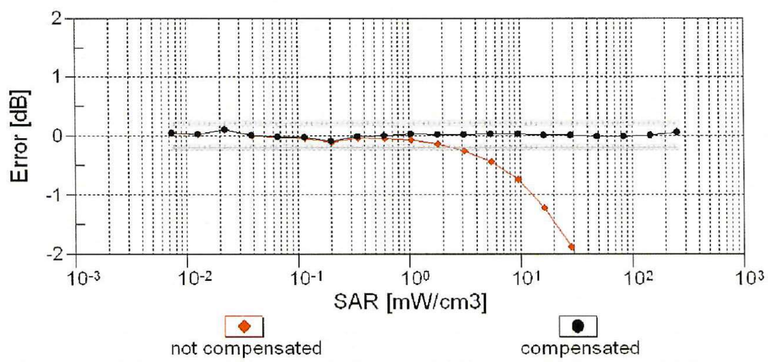




Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

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

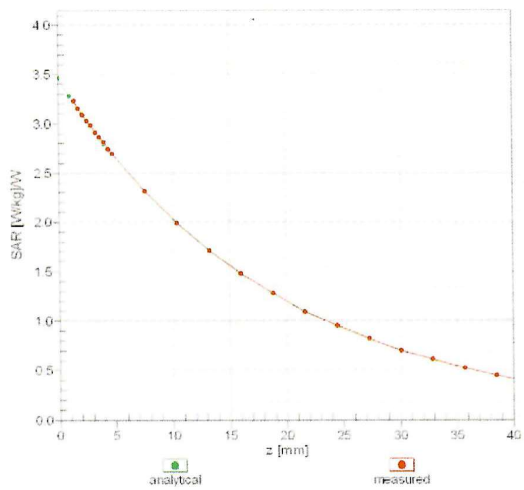




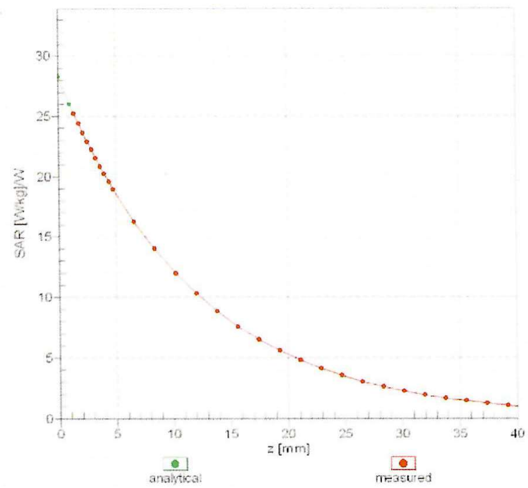
Uncertainty of Linearity Assessment: ± 0.6% (k=2)

Conversion Factor Assessment

f = 835 MHz,WGLS R9 (H_convF)

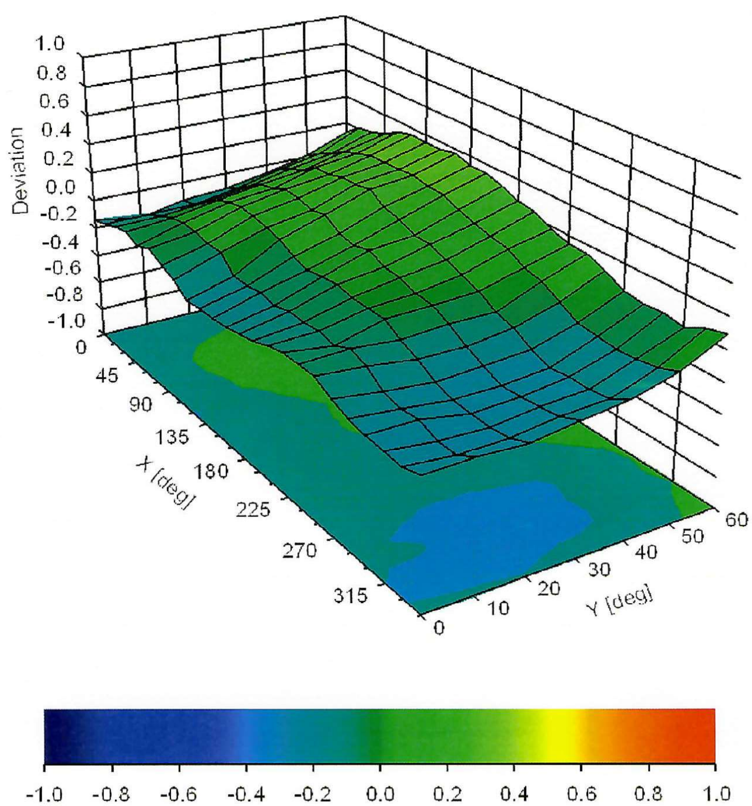


f = 1900 MHz,WGLS R22 (H_convF)



Deviation from Isotropy in Liquid

Error (ϕ, ϑ), f = 900 MHz



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

End of Test Report