

## APPENDIX D (PROBE CALIBRATION DATA)

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



**S** Schweizerischer Kalibrierdienst  
**C** Service suisse d'étalonnage  
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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 108**

Client **HCT (Dymstec)**

Certificate No: **H3-6101\_May11**

**CALIBRATION CERTIFICATE**

Object: **H3DV6 - SN:6101**

Calibration procedure(s): **QA CAL-03.v6, QA CAL-25.v3  
Calibration procedure for H-field probes optimized for close near field  
evaluations in air**

Calibration date: **May 18, 2011**

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 (MATE critical for calibration):

Primary Standards	ID	Cal Date (Certificate No.)	Scheduled Calibration
Power meter E4419B	GB41293674	31-Mar-11 (No. 217-01372)	Apr-12
Power sensor E4412A	MY41498067	31-Mar-11 (No. 217-01372)	Apr-12
Reference 3 dB Attenuator	SN: S5054 (3c)	29-Mar-11 (No. 217-01368)	Apr-12
Reference 20 dB Attenuator	SN: S5086 (20b)	29-Mar-11 (No. 217-01367)	Apr-12
Reference 30 dB Attenuator	SN: S5129 (30b)	29-Mar-11 (No. 217-01370)	Apr-12
Reference Probe H3DVB	SN: 6182	4-Oct-10 (No. H3-6182_Oct10)	Oct-11
DAE4	SN: 785	6-Apr-11 (No. DAE4-785_Apr11)	Apr-12
Secondary Standards	ID	Check Date (in house)	Scheduled Check
RF generator HP 8648C	US3642UD1700	4-Aug-99 (in house check Oct-09)	In house check: Oct-11
Network Analyzer HP 8753E	US37390585	18-Oct-01 (in house check Oct-10)	In house check: Oct-11

	Name	Function	Signature
Calibrated by:	Claudio Leubler	Laboratory Technician	
Approved by:	Katja Pokovic	Technical Manager	

Issued: May 19, 2011

This calibration certificate shall not be reproduced except in full without written approval of the laboratory.

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Accreditation No.: **SCS 108**

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Multilateral Agreement for the recognition of calibration certificates

**Glossary:**

**NORM<sub>x,y,z</sub>** sensitivity in free space  
**DCP** diode compression point  
**CF** crest factor (1/duty\_cycle) of the RF signal  
**A, B, C** modulation dependent linearization parameters  
**Polarization  $\varphi$**   $\varphi$  rotation around probe axis  
**Polarization  $\theta$**   $\theta$  rotation around an axis that is in the plane normal to probe axis (at measurement center),  
i.e.,  $\theta = 0$  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 1309-2005, "IEEE Standard for calibration of electromagnetic field sensors and probes, excluding antennas, from 9 kHz to 40 GHz", December 2005.

**Methods Applied and Interpretation of Parameters:**

- **NORM<sub>x,y,z</sub>**: Assessed for E-field polarization  $\theta = 0$  for XY sensors and  $\theta = 90$  for Z sensor ( $f \leq 900$  MHz in TEM-cell;  $f > 1800$  MHz: R22 waveguide).
- **X, Y, Z(f)  $a_0 a_1 a_2 = X, Y, Z, a_0 a_1 a_2$  frequency\_response** (see Frequency Response Chart).
- **DCP<sub>x,y,z</sub>**: 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.
- **A<sub>x,y,z</sub>; B<sub>x,y,z</sub>; C<sub>x,y,z</sub>; VR<sub>x,y,z</sub>**: A, B, C 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.
- **Spherical isotropy (3D deviation from isotropy)**: in a locally homogeneous field realized using an open waveguide setup.
- **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 X\_  $a_0 a_1 a_2$  (no uncertainty required).

H3DV6 - SN:6101

May 18, 2011

# Probe H3DV6

## SN:6101

Manufactured: December 10, 2001  
Calibrated: May 18, 2011

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

H3DV6- SN:6101

May 18, 2011

## DASY/EASY - Parameters of Probe: H3DV6 - SN:6101

### Basic Calibration Parameters

		Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm (A/m / $\sqrt{(mV)}$ )	a0	2.97E-003	2.96E-003	3.16E-003	$\pm 5.1\%$
Norm (A/m / $\sqrt{(mV)}$ )	a1	-8.75E-005	-1.29E-004	-1.54E-004	$\pm 5.1\%$
Norm (A/m / $\sqrt{(mV)}$ )	a2	-6.62E-005	-8.39E-005	-8.33E-006	$\pm 5.1\%$
DCP (mV) <sup>†</sup>		93.3	91.4	90.4	

### Modulation Calibration Parameters

UID	Communication System Name	PAR		A dB	B dB	C dB	VR mV	Unc <sup>‡</sup> (k=2)
10000	CW	0.00	X	0.00	0.00	1.00	121.8	$\pm 3.0\%$
			Y	0.00	0.00	1.00	123.4	
			Z	0.00	0.00	1.00	125.9	

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%.

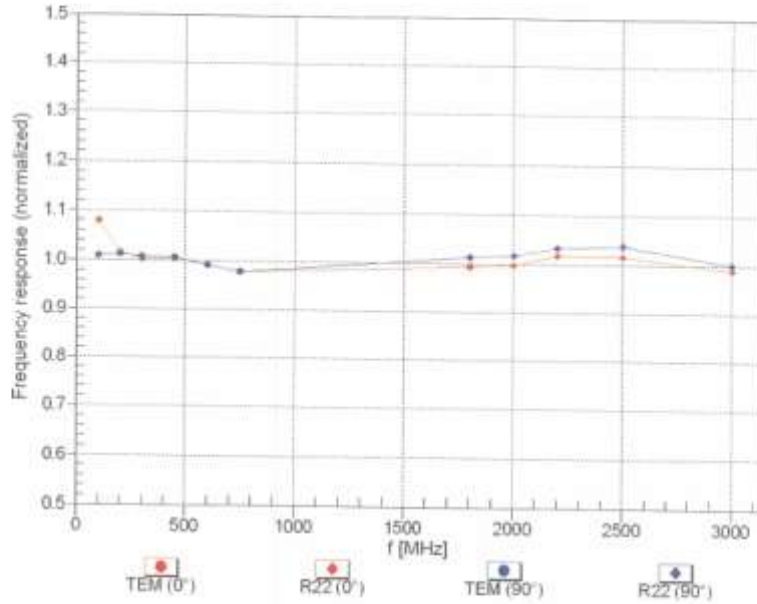
<sup>\*</sup> Numerical linearization parameter: uncertainty not required.

<sup>†</sup> Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

H3DV6-SN:6101

May 18, 2011

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

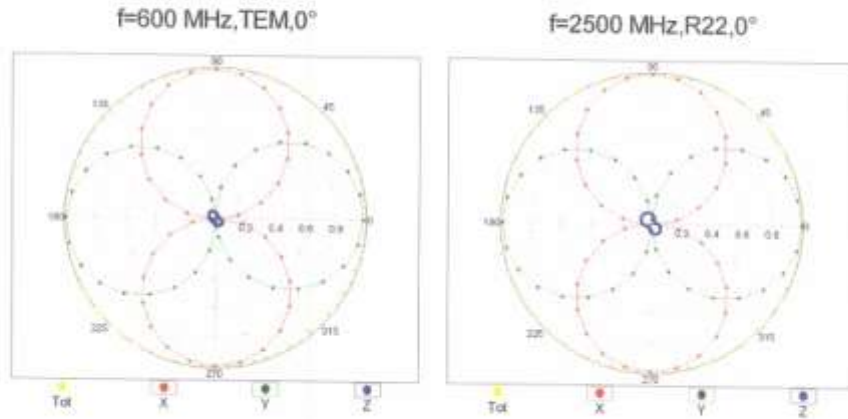


Uncertainty of Frequency Response of H-field:  $\pm 6.3\%$  (k=2)

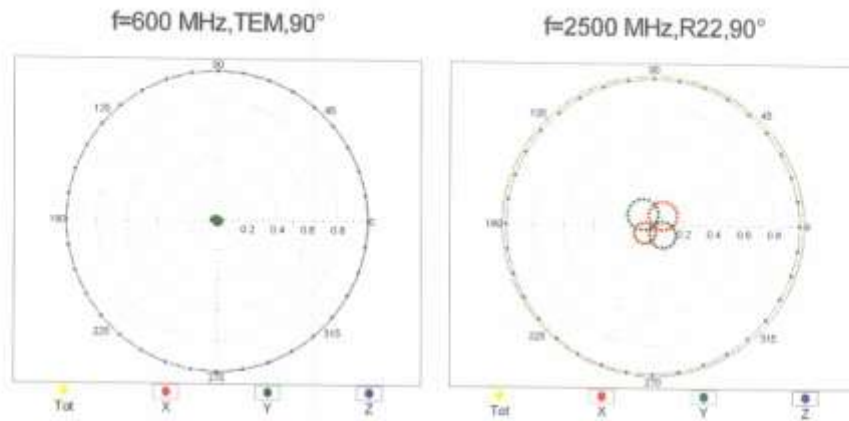
H3DV6- SN:6101

May 18, 2011

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



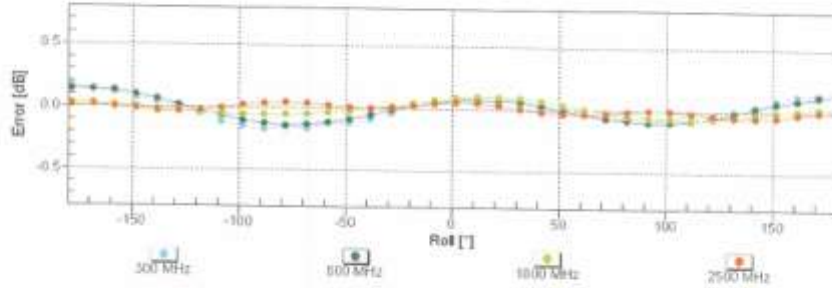
Receiving Pattern ( $\phi$ ),  $\theta = 90^\circ$



H3DV6-SN.6101

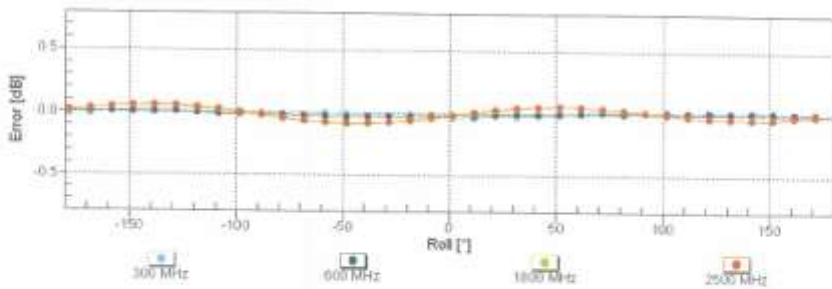
May 18, 2011

### Receiving Pattern ( $\phi$ ), $\vartheta = 0^\circ$



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

### Receiving Pattern ( $\phi$ ), $\vartheta = 90^\circ$



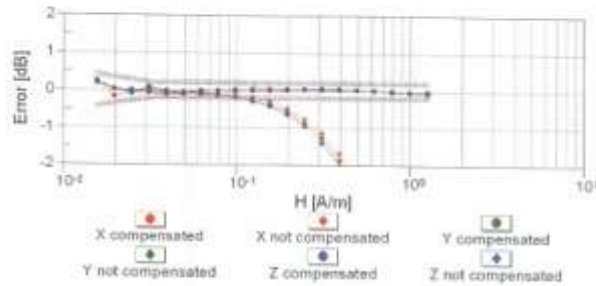
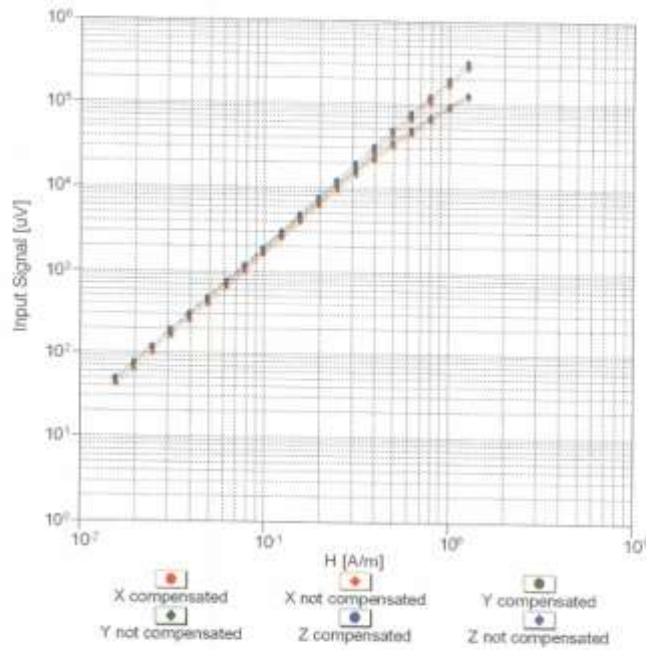
Uncertainty of Axial Isotropy Assessment:  $\pm 0.5\%$  ( $k=2$ )



H3DV6-SN:6101

May 18, 2011

### Dynamic Range f(H-field) (TEM cell, f = 900 MHz)



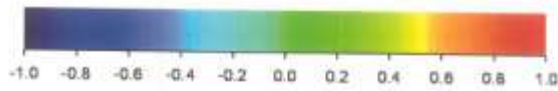
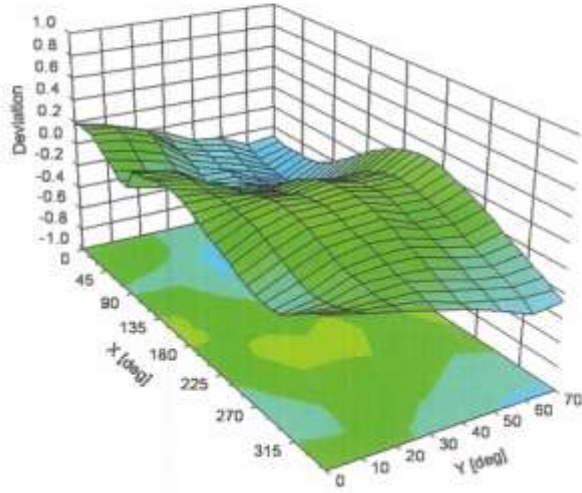
Uncertainty of Linearity Assessment:  $\pm 0.6\%$  (k=2)

H3DV6-SN:6101

May 18, 2011

### Deviation from Isotropy in Air

Error ( $\phi$ ,  $\theta$ ),  $f = 900$  MHz



Uncertainty of Spherical Isotropy Assessment:  $\pm 2.6\%$  ( $k=2$ )

H3DV6 - SN:6101

May 18, 2011

**DASY/EASY - Parameters of Probe: H3DV6 - SN:6101****Other Probe Parameters**

Sensor Arrangement	Rectangular
Connector Angle (°)	-38.4
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	337 mm
Probe Body Diameter	10 mm
Tip Length	20 mm
Tip Diameter	6 mm
Probe Tip to Sensor X Calibration Point	3 mm
Probe Tip to Sensor Y Calibration Point	3 mm
Probe Tip to Sensor Z Calibration Point	3 mm

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Accreditation No.: **SCS 108**

Client **HCT (Dymstec)**

Certificate No: **ER3-2343\_May11**

**CALIBRATION CERTIFICATE**

Object: **ER3DV6 - SN:2343**

Calibration procedure(s): **QA CAL-02.v6, QA CAL-25.v3  
Calibration procedure for E-field probes optimized for close near field  
evaluations in air**

Calibration date: **May 16, 2011**

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 E4419B	GB41293874	31-Mar-11 (No. 217-01372)	Apr-12
Power sensor E4412A	MY41496057	31-Mar-11 (No. 217-01372)	Apr-12
Reference 3 dB Attenuator	SN: 55054 (3c)	29-Mar-11 (No. 217-01369)	Apr-12
Reference 20 dB Attenuator	SN: 55086 (20b)	29-Mar-11 (No. 217-01367)	Apr-12
Reference 30 dB Attenuator	SN: 55123 (30b)	29-Mar-11 (No. 217-01370)	Apr-12
Reference Probe ER3DV6	SN: 2328	4-Oct-10 (No. ER3-2328_Oct10)	Oct-11
DAE4	SN: 789	6-Apr-11 (No. DAE4-789_Apr11)	Apr-12
Secondary Standards	ID	Check Date (in house)	Scheduled Check
RF generator HP 8948C	US3642U01700	4-Aug-09 (in house check Oct-09)	In house check: Oct-11
Network Analyzer HP 8753E	US37390585	18-Oct-01 (in house check Oct-10)	In house check: Oct-11

Calibrated by:	Name <b>Claudio Leubler</b>	Function Laboratory Technician	Signature 
Approved by:	Name <b>Katja Pokovic</b>	Function Technical Manager	Signature 

Issued: May 16, 2011

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**Glossary:**

NORM <sub>x,y,z</sub>	sensitivity in free space
DCP	diode compression point
CF	crest factor (1/duty_cycle) of the RF signal
A, B, C	modulation dependent linearization parameters
Polarization $\varphi$	$\varphi$ rotation around probe axis
Polarization $\theta$	$\theta$ rotation around an axis that is in the plane normal to probe axis (at measurement center), i.e., $\theta = 0$ is normal to probe axis
Connector Angle	information used in DASYS system to align probe sensor X to the robot coordinate system

**Calibration is Performed According to the Following Standards:**

- a) IEEE Std 1309-2005, "IEEE Standard for calibration of electromagnetic field sensors and probes, excluding antennas, from 9 kHz to 40 GHz", December 2005.

**Methods Applied and Interpretation of Parameters:**

- NORM<sub>x,y,z</sub>: Assessed for E-field polarization  $\theta = 0$  for XY sensors and  $\theta = 90$  for Z sensor ( $f \leq 900$  MHz in TEM-cell;  $f > 1800$  MHz: R22 waveguide).
- NORM(f)<sub>x,y,z</sub> = NORM<sub>x,y,z</sub> \* frequency\_response (see Frequency Response Chart).
- DCP<sub>x,y,z</sub>: 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.
- Ax,y,z; Bx,y,z; Cx,y,z; VRx,y,z: A, B, C 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.
- Spherical isotropy (3D deviation from isotropy): in a locally homogeneous field realized using an open waveguide setup.
- 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<sub>x</sub> (no uncertainty required).

ER3DV6 - SN:2343

May 16, 2011

# Probe ER3DV6

## SN:2343

Manufactured: December 14, 2004  
Calibrated: May 16, 2011

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

ER3DV6- SN:2343

May 16, 2011

## DASY/EASY - Parameters of Probe: ER3DV6 - SN:2343

### Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ( $\mu\text{V}/(\text{V}/\text{m})^2$ )	1.65	1.61	1.62	$\pm 10.1 \%$
DCP (mV) <sup>2</sup>	96.8	100.4	98.7	

### Modulation Calibration Parameters

UID	Communication System Name	PAR		A dB	B dB	C dB	VR mV	Unc <sup>c</sup> (k=2)
10000	CW	0.00	X	0.00	0.00	1.00	120.8	$\pm 2.7 \%$
			Y	0.00	0.00	1.00	112.2	
			Z	0.00	0.00	1.00	100.8	

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%.

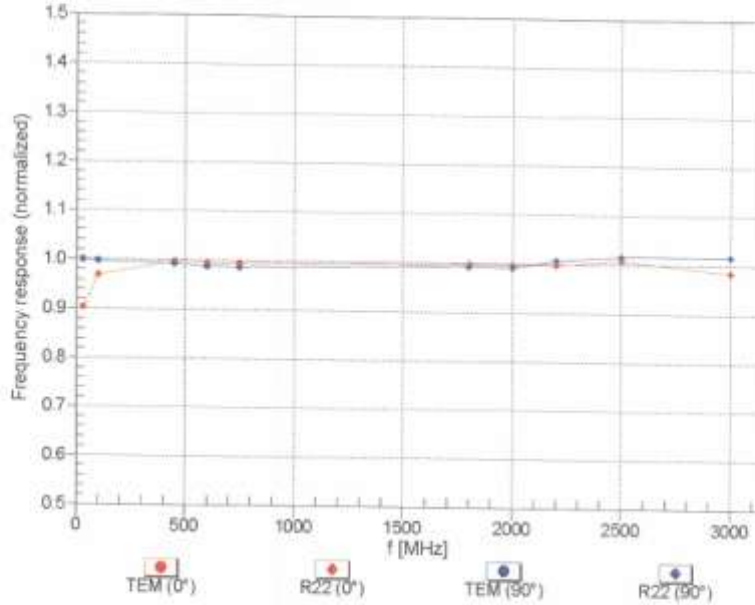
<sup>a</sup> Numerical linearization parameter: uncertainty not required.

<sup>b</sup> Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

ER3DV6-SN:2343

May 16, 2011

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



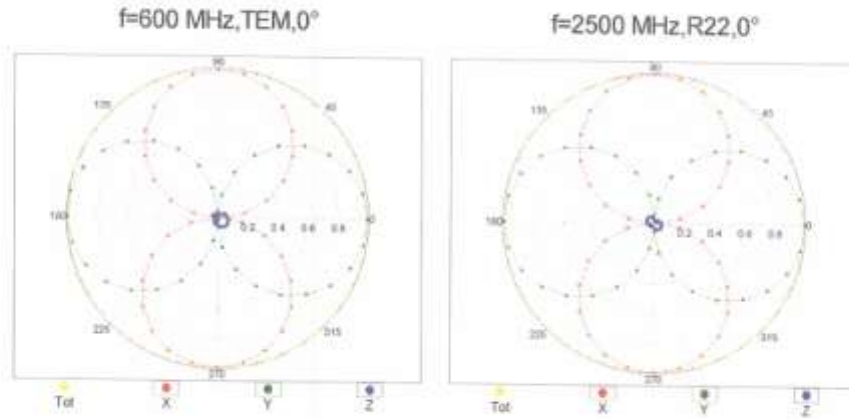
Uncertainty of Frequency Response of E-field:  $\pm 6.3\%$  (k=2)



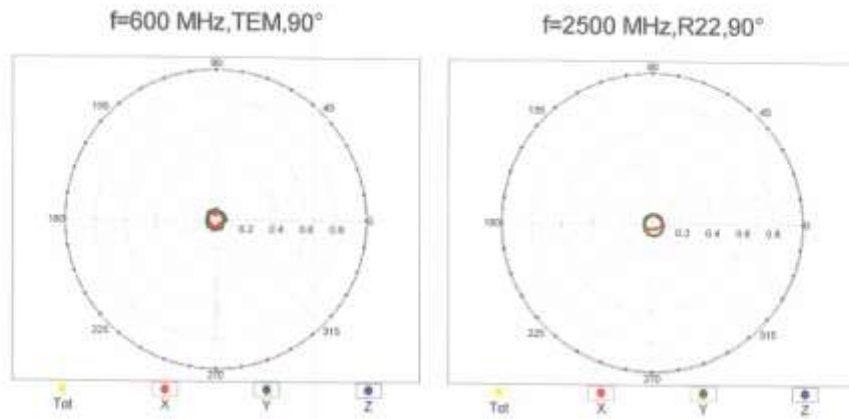
ER3DV6- SN:2343

May 16, 2011

Receiving Pattern ( $\phi$ ),  $\vartheta = 0^\circ$



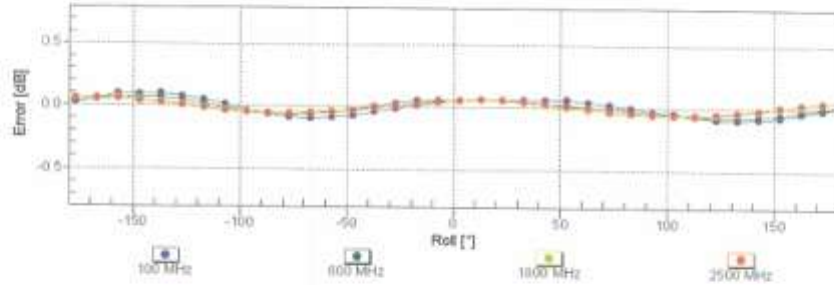
Receiving Pattern ( $\phi$ ),  $\vartheta = 90^\circ$



ER3DV6-SN:2343

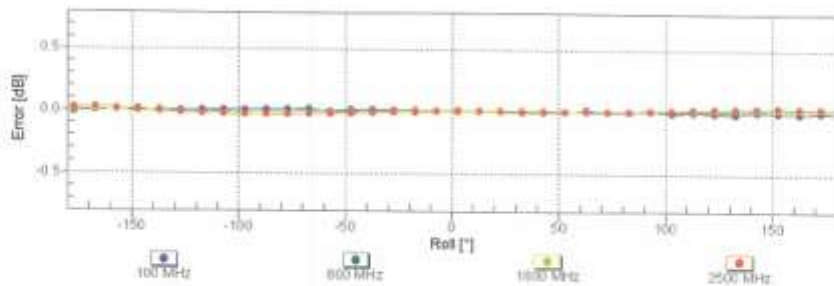
May 16, 2011

### Receiving Pattern ( $\phi$ ), $\vartheta = 0^\circ$



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

### Receiving Pattern ( $\phi$ ), $\vartheta = 90^\circ$

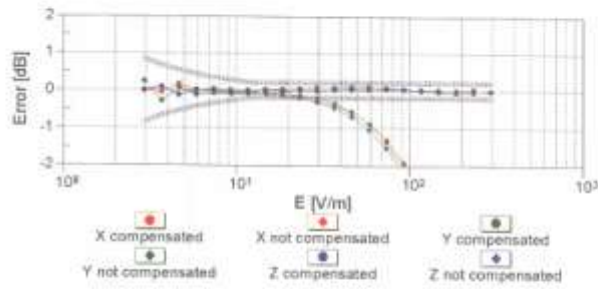
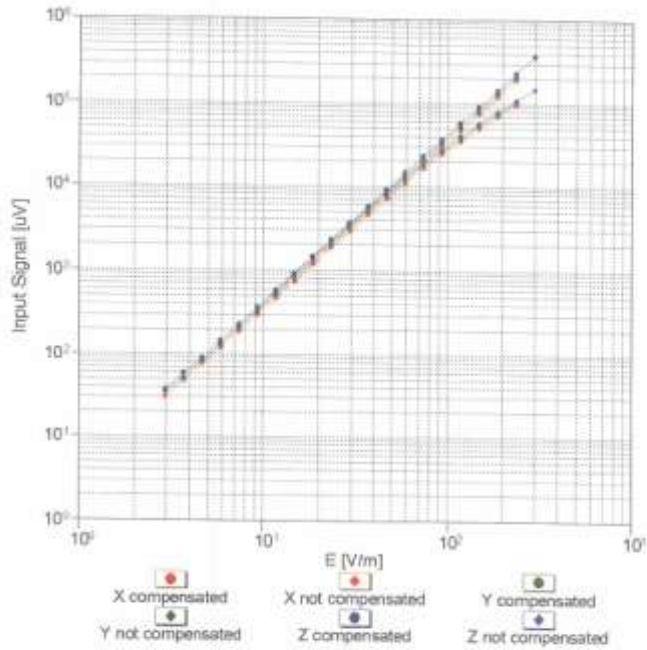


Uncertainty of Axial Isotropy Assessment:  $\pm 0.5\%$  ( $k=2$ )

ER3DV6- SN:2343

May 16, 2011

### Dynamic Range f(E-field) (TEM cell , f = 900 MHz)



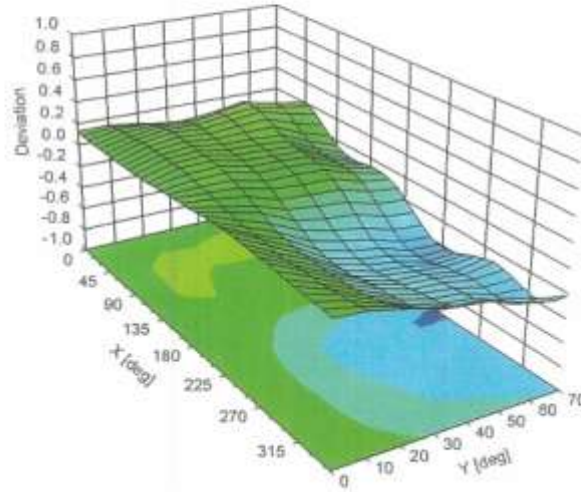
Uncertainty of Linearity Assessment:  $\pm 0.6\%$  (k=2)

ER3DV6- SN.2343

May 16, 2011

### Deviation from Isotropy in Air

Error ( $\phi, \theta$ ),  $f = 900$  MHz

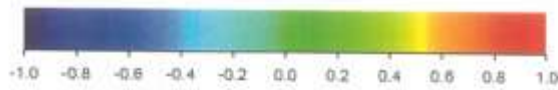
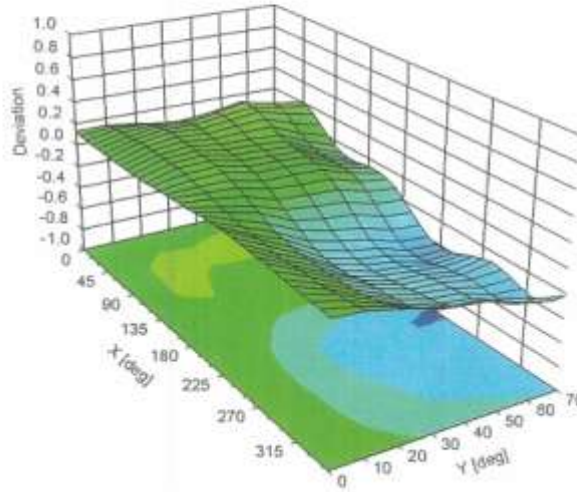


Uncertainty of Spherical Isotropy Assessment:  $\pm 2.6\%$  ( $k=2$ )

ER3DV8- SN-2343

May 16, 2011

### Deviation from Isotropy in Air Error ( $\phi$ , $\theta$ ), $f = 900$ MHz



Uncertainty of Spherical Isotropy Assessment:  $\pm 2.6\%$  ( $k=2$ )

ER3DV6- SN:2343

May 16, 2011

**DASY/EASY - Parameters of Probe: ER3DV6 - SN:2343****Other Probe Parameters**

Sensor Arrangement	Rectangular
Connector Angle (°)	62.8
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	337 mm
Probe Body Diameter	10 mm
Tip Length	10 mm
Tip Diameter	8 mm
Probe Tip to Sensor X Calibration Point	2.5 mm
Probe Tip to Sensor Y Calibration Point	2.5 mm
Probe Tip to Sensor Z Calibration Point	2.5 mm