# APPENDIX D (PROBE CALIBRATION DATA)

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

ilac-MRA

SWISS CALIBRATION

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The Swiss Accreditation Service is one of the signatories to the EA
Multilateral Agreement for the recognition of calibration certificates

| Client | **HCT (Dymstec)** | Certificate No: **ER3-2343_May09** |
|---|---|---|

## CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | ER3DV6 - SN:2343 |
| Calibration procedure(s) | **QA CAL-02.v5**<br>**Calibration procedure for E-field probes optimized for close near field evaluations in air** |
| Calibration date: | May 22, 2009 |
| Condition of the calibrated item | In Tolerance |

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 | 1-Apr-09 (No. 217-01030) | Apr-10 |
| Power sensor E4412A | MY41495277 | 1-Apr-09 (No. 217-01030) | Apr-10 |
| Power sensor E4412A | MY41498087 | 1-Apr-09 (No. 217-01030) | Apr-10 |
| Reference 3 dB Attenuator | SN: S5054 (3c) | 31-Mar-09 (No. 217-01026) | Mar-10 |
| Reference 20 dB Attenuator | SN: S5086 (20b) | 31-Mar-09 (No. 217-01028) | Mar-10 |
| Reference 30 dB Attenuator | SN: S5129 (30b) | 31-Mar-09 (No. 217-01027) | Mar-10 |
| Reference Probe ER3DV6 | SN: 2328 | 1-Oct-08 (No. ER3-2328_Oct08) | Oct-09 |
| DAE4 | SN: 789 | 19-Dec-08 (No. DAE4-789_Dec08) | Dec-09 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---|---|---|---|
| RF generator HP 8648C | US3642U01700 | 4-Aug-99 (in house check Oct-07) | In house check: Oct-09 |
| Network Analyzer HP 8753E | US37390585 | 18-Oct-01 (in house check Oct-08) | In house check: Oct-09 |

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

Issued: May 25, 2009

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

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Accreditation No.: **SCS 108**

## Glossary:

| | |
|---|---|
| NORMx,y,z | sensitivity in free space |
| DCP | diode compression point |
| Polarization $\varphi$ | $\varphi$ rotation around probe axis |
| Polarization $\vartheta$ | $\vartheta$ 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:

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:

- *NORMx,y,z*: Assessed for E-field polarization $\vartheta = 0$ for XY sensors and $\vartheta = 90$ for Z sensor ($f \leq 900$ MHz in TEM-cell; f > 1800 MHz: R22 waveguide).

- *NORM(f)x,y,z = NORMx,y,z \* frequency_response* (see Frequency Response Chart).

- *DCPx,y,z*: DCP are numerical linearization parameters assessed based on the data of power sweep (no uncertainty required). DCP does not depend on frequency.

- *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 *NORMx* (no uncertainty required).

ER3DV6 SN:2343                                                                          May 22, 2009

# Probe ER3DV6

## SN:2343

Manufactured:        December 14, 2004
Last calibrated:      May 19, 2008
Recalibrated:         May 22, 2009

### Calibrated for DASY Systems

(Note: non-compatible with DASY2 system!)

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ER3DV6 SN:2343                                                    May 22, 2009

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

Sensitivity in Free Space [$\mu V/(V/m)^2$]                    Diode Compression$^A$

|  |  |  |  |
|---|---|---|---|
| NormX | 1.68 ± 10.1 % (k=2) | DCP X | 92 mV |
| NormY | 1.63 ± 10.1 % (k=2) | DCP Y | 94 mV |
| NormZ | 1.63 ± 10.1 % (k=2) | DCP Z | 97 mV |

Frequency Correction

| X | 0.0 |
|---|---|
| Y | 0.0 |
| Z | 0.0 |

Sensor Offset            (Probe Tip to Sensor Center)

| X | 2.5 mm |
|---|---|
| Y | 2.5 mm |
| Z | 2.5 mm |

Connector Angle            63 °

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%.

$^A$ numerical linearization parameter: uncertainty not required

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ER3DV6 SN:2343  May 22, 2009
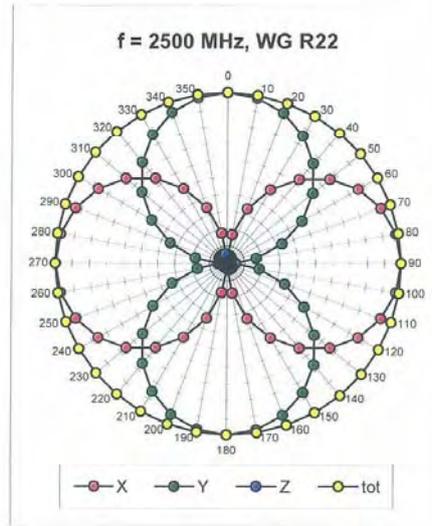
## Frequency Response of E-Field

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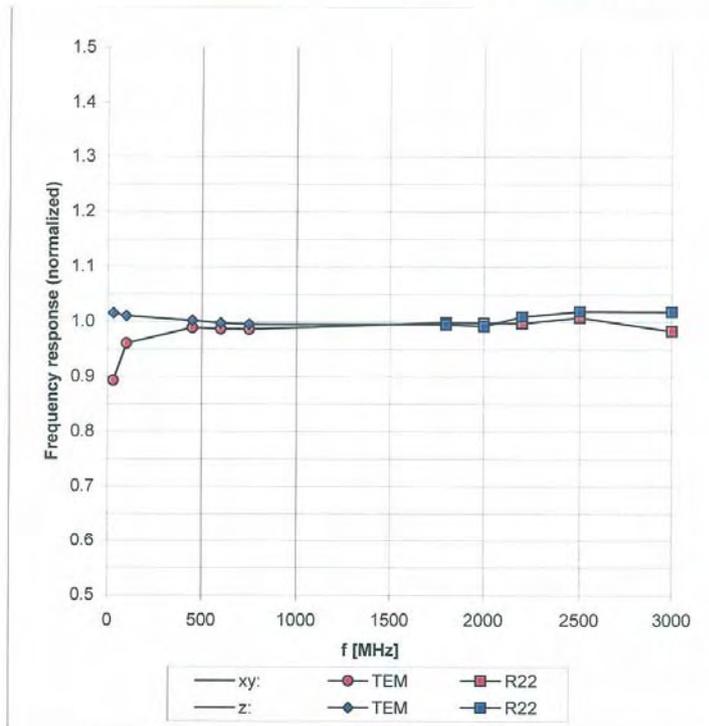


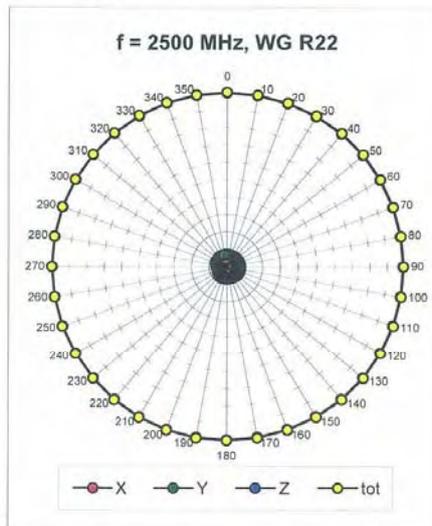Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

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ER3DV6 SN:2343

May 22, 2009

## Receiving Pattern (φ), ϑ = 0°

f = 600 MHz, TEM ifi110EXX

f = 2500 MHz, WG R22

X — Y — Z — tot

X — Y — Z — tot

## Receiving Pattern (φ), ϑ = 90°

f = 600 MHz, TEM ifi110EXX

f = 2500 MHz, WG R22

X — Y — Z — tot

X — Y — Z — tot
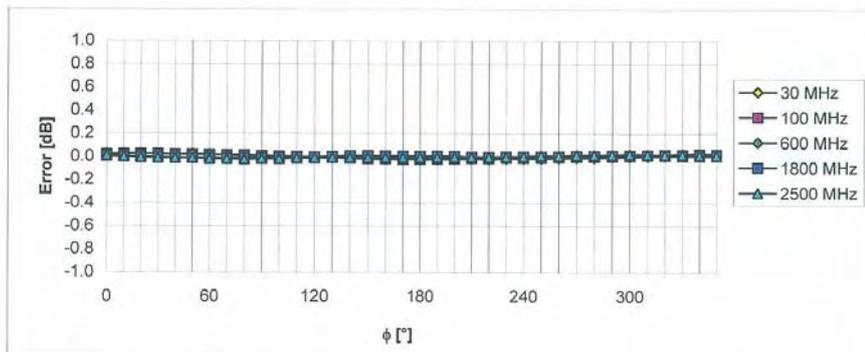
Certificate No: ER3-2343_May09

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ER3DV6 SN:2343

May 22, 2009

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



Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)
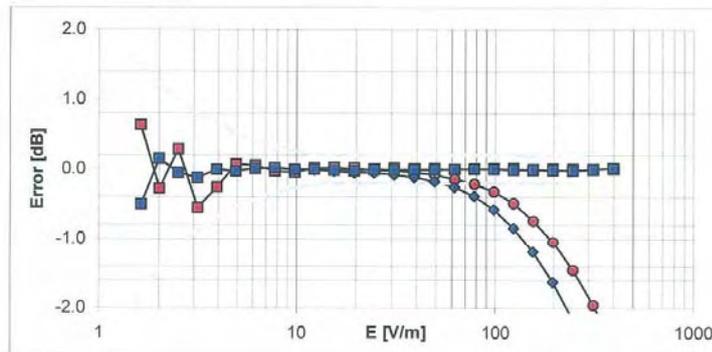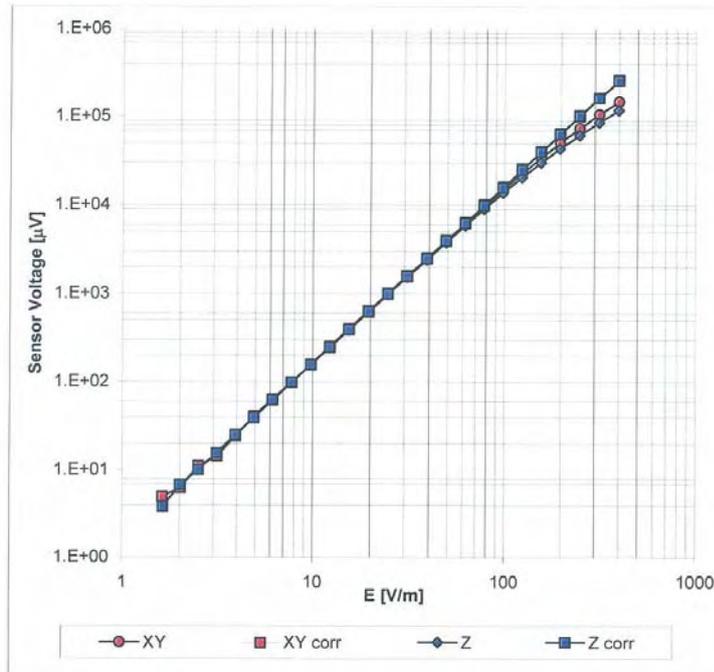
## Receiving Pattern ($\phi$), $\vartheta$ = 90°



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

Certificate No: ER3-2343_May09          Page 7 of 9
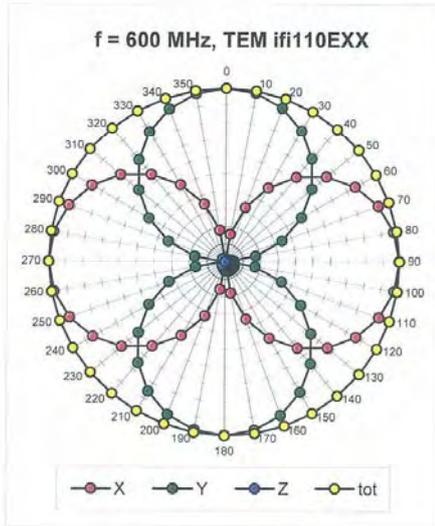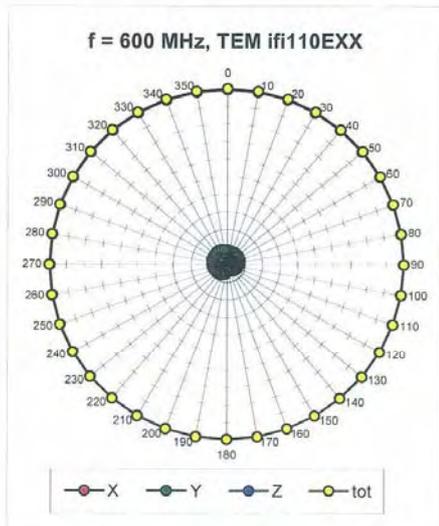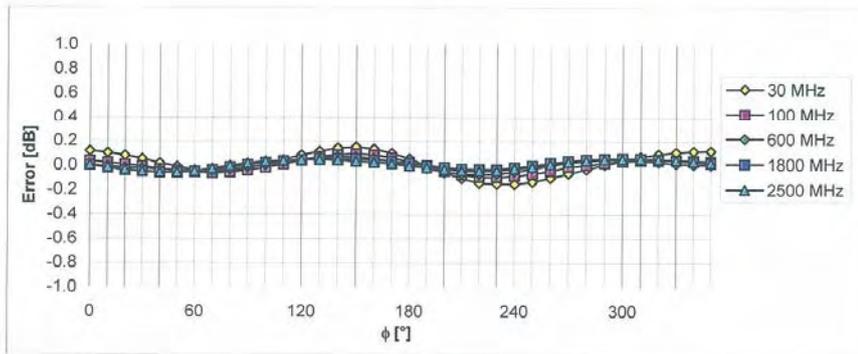
ER3DV6 SN:2343                                                                May 22, 2009

## Dynamic Range f(E-field)
### (Waveguide R22, f = 1800 MHz)



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

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ER3DV6 SN:2343

May 22, 2009

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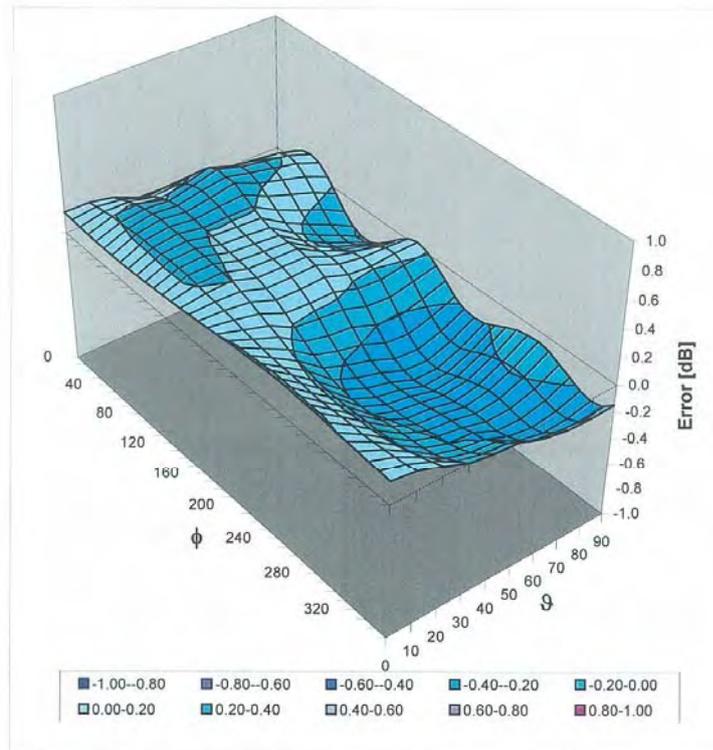


Uncertainty of Spherical Isotropy Assessment: ± 2.6% (k=2)

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Accreditation No.: **SCS 108**

| Client | **HCT (Dymstec)** | Certificate No: **H3-6101_May09** |
|---|---|---|

## CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | H3DV6 - SN:6101 |
| Calibration procedure(s) | QA CAL-03.v5<br>Calibration procedure for H-field probes optimized for close near field evaluations in air |
| Calibration date: | May 22, 2009 |
| Condition of the calibrated item | In Tolerance |

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%.

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| Primary Standards | ID # | Cal Date (Certificate No.) | Scheduled Calibration |
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| Reference 30 dB Attenuator | SN: S5129 (30b) | 31-Mar-09 (No. 217-01027) | Mar-10 |
| Reference Probe H3DV6 | SN: 6182 | 1-Oct-08 (No. H3-6182_Oct08) | Oct-09 |
| DAE4 | SN: 789 | 19-Dec-08 (No. DAE4-789_Dec08) | Dec-09 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---|---|---|---|
| RF generator HP 8648C | US3642U01700 | 4-Aug-99 (in house check Oct-07) | In house check: Oct-09 |
| Network Analyzer HP 8753E | US37390585 | 18-Oct-01 (in house check Oct-08) | In house check: Oct-09 |

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

Issued: May 25, 2009

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**Accreditation No.: SCS 108**

## Glossary:

| | |
|---|---|
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| DCP | diode compression point |
| 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 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:

- $X,Y,Z\_a0a1a2$: Assessed for E-field polarization $\vartheta$ = 90 for XY sensors and $\vartheta$ = 0 for Z sensor (f ≤ 900 MHz in TEM-cell; f > 1800 MHz: R22 waveguide).

- $X,Y,Z(f)\_a0a1a2 = X,Y,Z\_a0a1a2 *$ frequency_response (see Frequency Response Chart).

- $DCPx,y,z$: DCP are numerical linearization parameters assessed based on the data of power sweep (no uncertainty required). DCP does not depend on frequency.

- 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 $X\_a0a1a2$ (no uncertainty required).

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H3DV6 SN:6101

May 22, 2009

# Probe  H3DV6

## SN:6101

| | |
|---|---|
| Manufactured: | December 10, 2001 |
| Last calibrated: | May 19, 2008 |
| Recalibrated: | May 22, 2009 |

Calibrated for DASY Systems

(Note: non-compatible with DASY2 system!)

Certificate No: H3-6101_May09              Page 3 of 9

H3DV6 SN:6101 May 22, 2009

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

Sensitivity in Free Space [A/m / $\sqrt{(\mu V)}$]

|   | a0 | a1 | a2 |   |
|---|---|---|---|---|
| X | 2.945E-03 | -9.310E-5 | -8.342E-6 | ± 5.1 % (k=2) |
| Y | 2.924E-03 | -1.510E-4 | -3.093E-5 | ± 5.1 % (k=2) |
| Z | 3.293E-03 | -5.896E-5 | 1.890E-5 | ± 5.1 % (k=2) |

Diode Compression[1]

| DCP X | 82 mV |
|---|---|
| DCP Y | 93 mV |
| DCP Z | 84 mV |

Sensor Offset        (Probe Tip to Sensor Center)

| X | 3.0 mm |
|---|---|
| Y | 3.0 mm |
| Z | 3.0 mm |

Connector Angle        -63 °

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%.
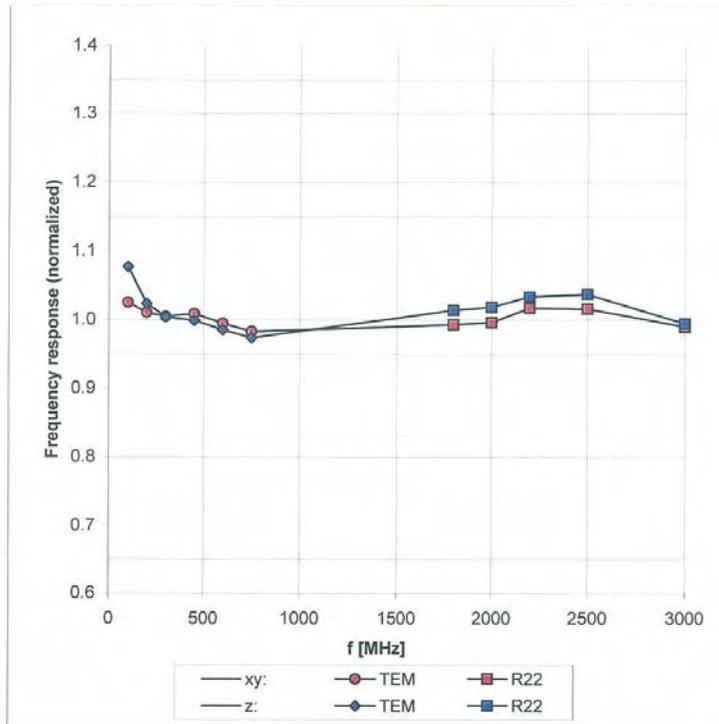
[1] numerical linearization parameter: uncertainty not required

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H3DV6 SN:6101                                                        May 22, 2009

## Frequency Response of H-Field

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


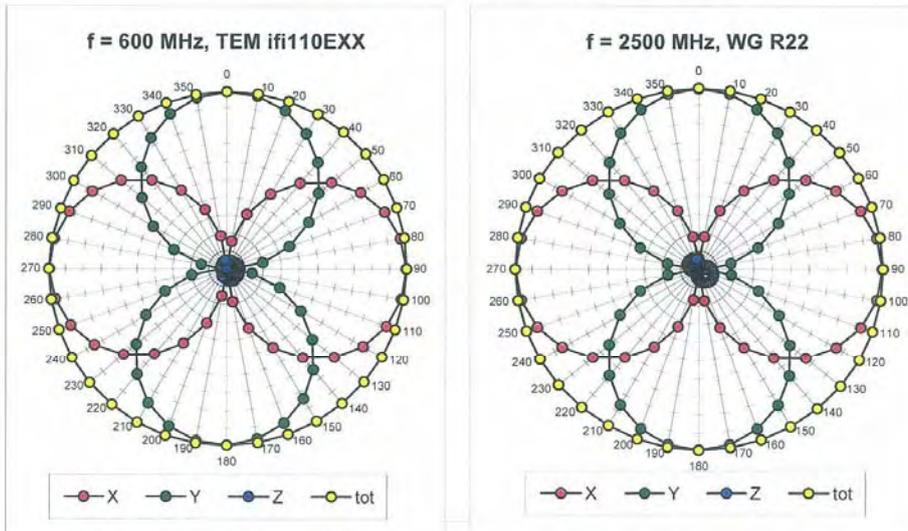
Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

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H3DV6 SN:6101                                          May 22, 2009

## Receiving Pattern (φ), ϑ = 90°

f = 600 MHz, TEM ifi110EXX

f = 2500 MHz, WG R22

## Receiving Pattern (φ), ϑ = 0°

f = 600 MHz, TEM ifi110EXX

f = 2500 MHz, WG R22

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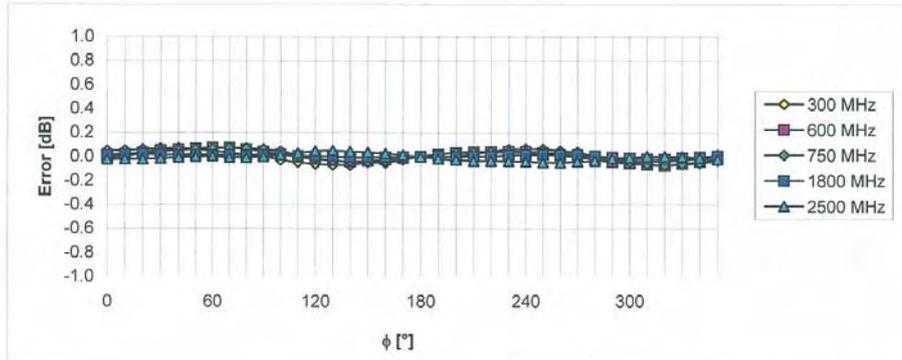H3DV6 SN:6101                                                                                          May 22, 2009

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



Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)
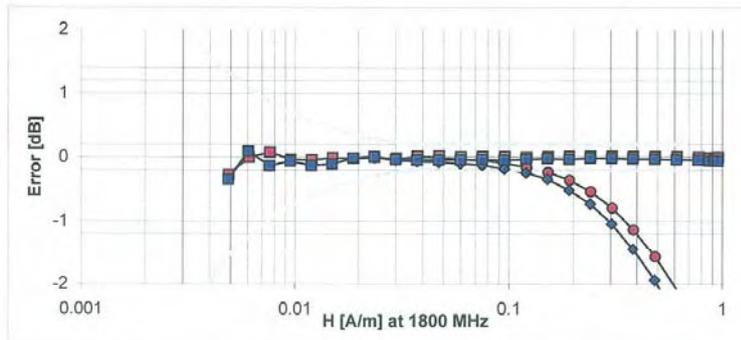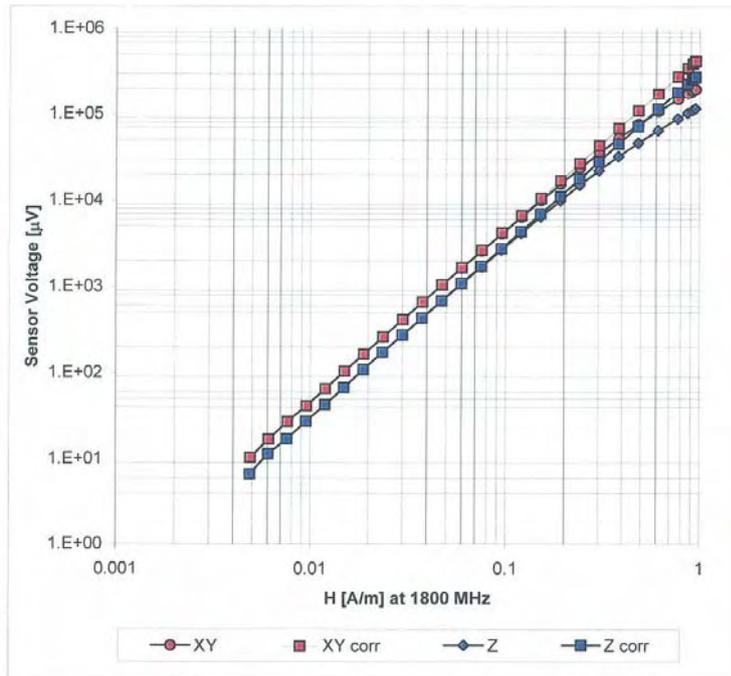
## Receiving Pattern ($\phi$), $\vartheta$ = 0°



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

Certificate No: H3-6101_May09                          Page 7 of 9
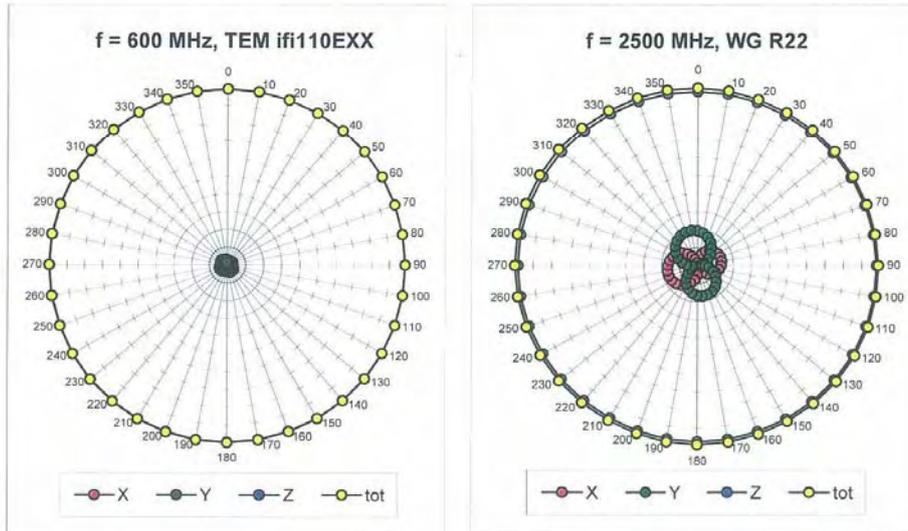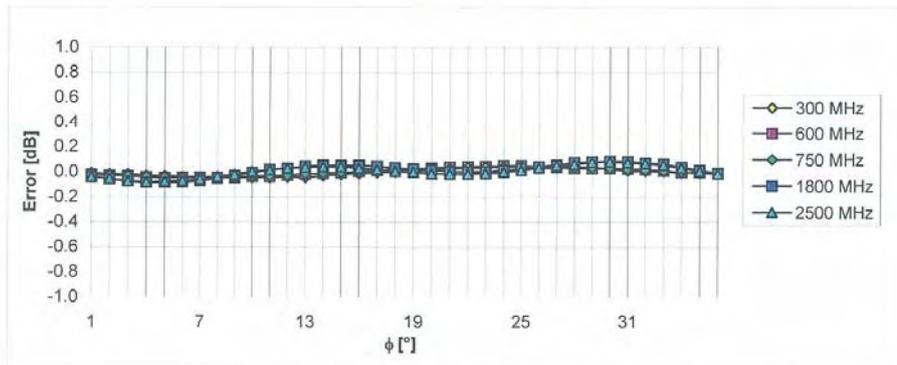
H3DV6 SN:6101                                                    May 22, 2009

## Dynamic Range f(H-field)
### (Waveguide R22, f = 1800 MHz)



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

Certificate No: H3-6101_May09                    Page 8 of 9

H3DV6 SN:6101                                                                May 22, 2009

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



| -1.00--0.80 | -0.80--0.60 | -0.60--0.40 | -0.40--0.20 | -0.20-0.00 |
| 0.00-0.20 | 0.20-0.40 | 0.40-0.60 | 0.60-0.80 | 0.80-1.00 |

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

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