

## Appendix D – Probe Calibration Data Sheets

# NCL CALIBRATION LABORATORIES

Calibration File No.: CP-609

Client.: RFEL

## CERTIFICATE OF CALIBRATION

It is certified that the equipment identified below has been calibrated in the  
**NCL CALIBRATION LABORATORIES** by qualified personnel following recognized  
procedures and using transfer standards traceable to NRC/NIST.

Equipment: Miniature Isotropic RF Probe 5800 MHz

Manufacturer: APREL Laboratories

Model No.: E-020

Serial No.: 215

BODY Calibration

Calibration Procedure: SSI/DRB-TP-D01-032-E020-V2

Project No: RFEL-Probe-215-Calibration-5166

Calibrated: 10<sup>th</sup> June 2005  
Released on: 10<sup>th</sup> June 2005

This Calibration Certificate is Incomplete Unless Accompanied with the Calibration Results Summary

Released By: \_\_\_\_\_ Signature On File

**NCL CALIBRATION LABORATORIES**

51 SPECTRUM WAY  
NEPEAN, ONTARIO  
CANADA K2R 1E6

Division of APREL Lab.  
TEL: (613) 820-4988  
FAX: (613) 820-4161

## **Introduction**

This Calibration Report reproduces the results of the calibration performed in line with the SSI/DRB-TP-D01-032-E020-V2 E-Field Probe Calibration Procedure. The results contained within this report are for APREL E-Field Probe E-020 215.

## **References**

SSI/DRB-TP-D01-032-E020-V2 E-Field Probe Calibration Procedure  
IEEE 1528 "Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body Due to Wireless Communications Devices: Experimental Techniques"  
SSI-TP-011 Tissue Calibration Procedure

## **Conditions**

Probe 215 was a new probe taken from stock prior to calibration.

**Ambient Temperature of the Laboratory:** 22 °C +/- 0.5°C  
**Temperature of the Tissue:** 21 °C +/- 0.5°C

**We the undersigned attest that to the best of our knowledge the calibration of this probe has been accurately conducted and that all information contained within this report has been reviewed for accuracy.**

---

**Stuart Nicol**  
**Director Product Development**

---

**Janusz Lokaj**  
**Member of Engineering Staff**  
**(Calibration Engineer)**

## Calibration Results Summary

<b>Probe Type:</b>	E-Field Probe E-020
<b>Serial Number:</b>	215
<b>Frequency:</b>	5800 MHz
<b>Sensor Offset:</b>	1.56 mm
<b>Sensor Length:</b>	2.5 mm
<b>Tip Enclosure:</b>	Ertalyte*
<b>Tip Diameter:</b>	<5 mm
<b>Tip Length:</b>	60 mm
<b>Total Length:</b>	290 mm

\*Resistive to recommended tissue recipes per IEEE-1528

## Sensitivity in Air

<b>Channel X:</b>	$1.2 \mu\text{V}/(\text{V}/\text{m})^2$
<b>Channel Y:</b>	$1.2 \mu\text{V}/(\text{V}/\text{m})^2$
<b>Channel Z:</b>	$1.2 \mu\text{V}/(\text{V}/\text{m})^2$
<b>Diode Compression Point:</b>	95 mV

## **Sensitivity in Body Tissue**

**Frequency:** 5800 MHz

**Epsilon:** 49.6 (+/-5%)                      **Sigma:** 6.25 S/m (+/-10%)

### **ConvF**

**Channel X:** 2.1

**Channel Y:** 2.1

**Channel Z:** 2.1

Tissue sensitivity values were calculated using the load impedance of the APREL Laboratories Daq-Paq.

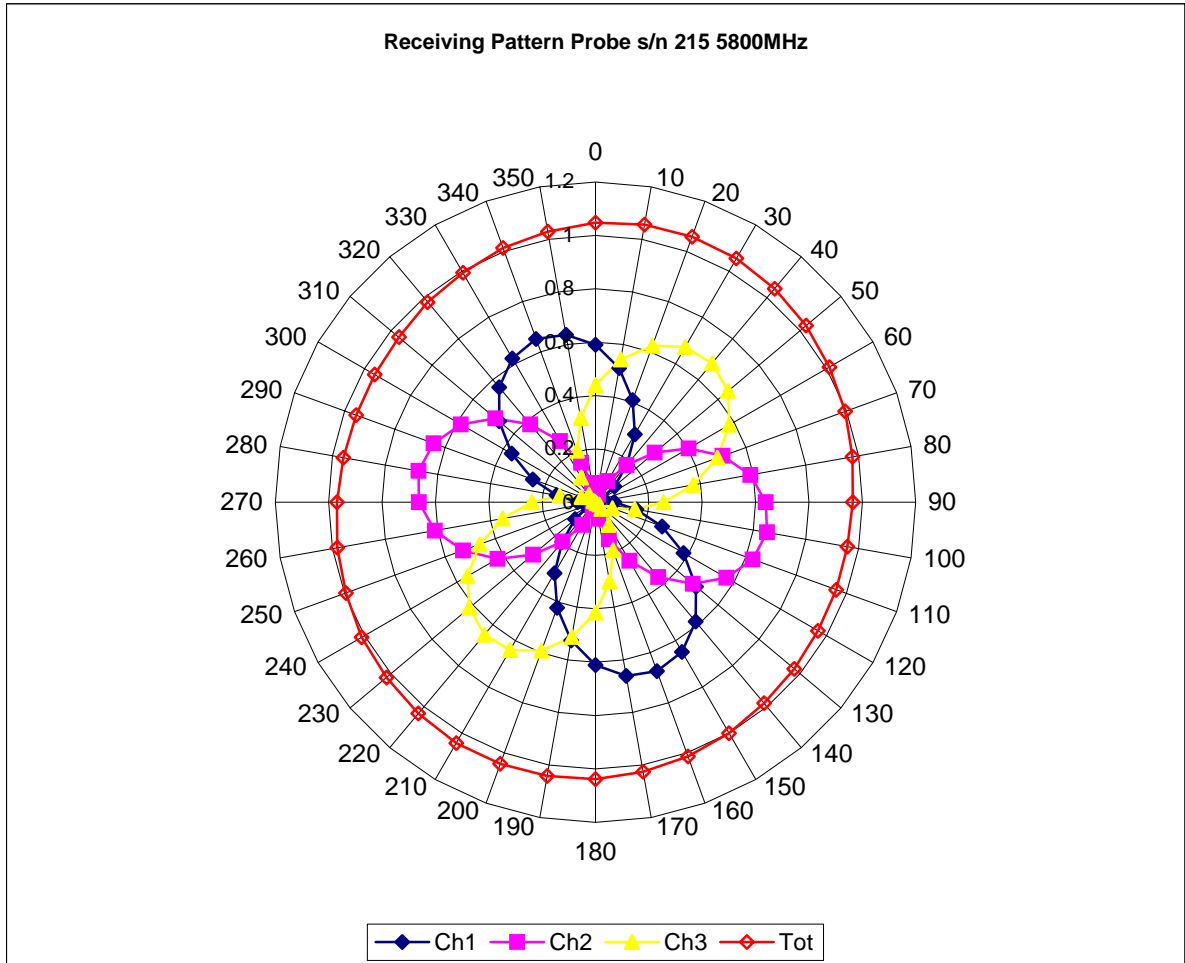
### **Boundary Effect:**

Uncertainty resulting from the boundary effect is less than 2% for the distance between the tip of the probe and the tissue boundary, when less than 2.44mm.

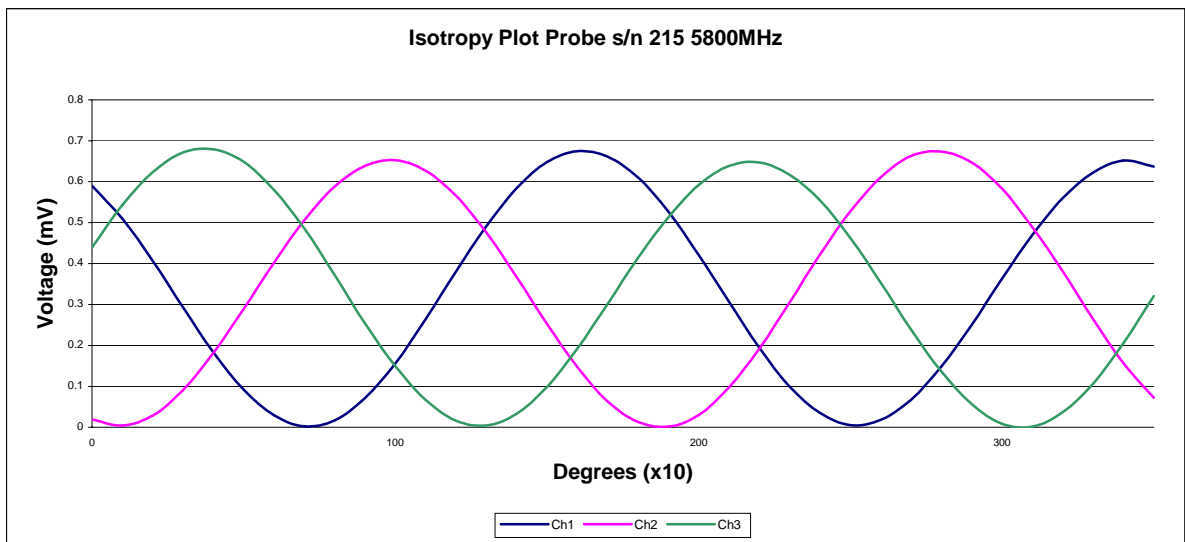
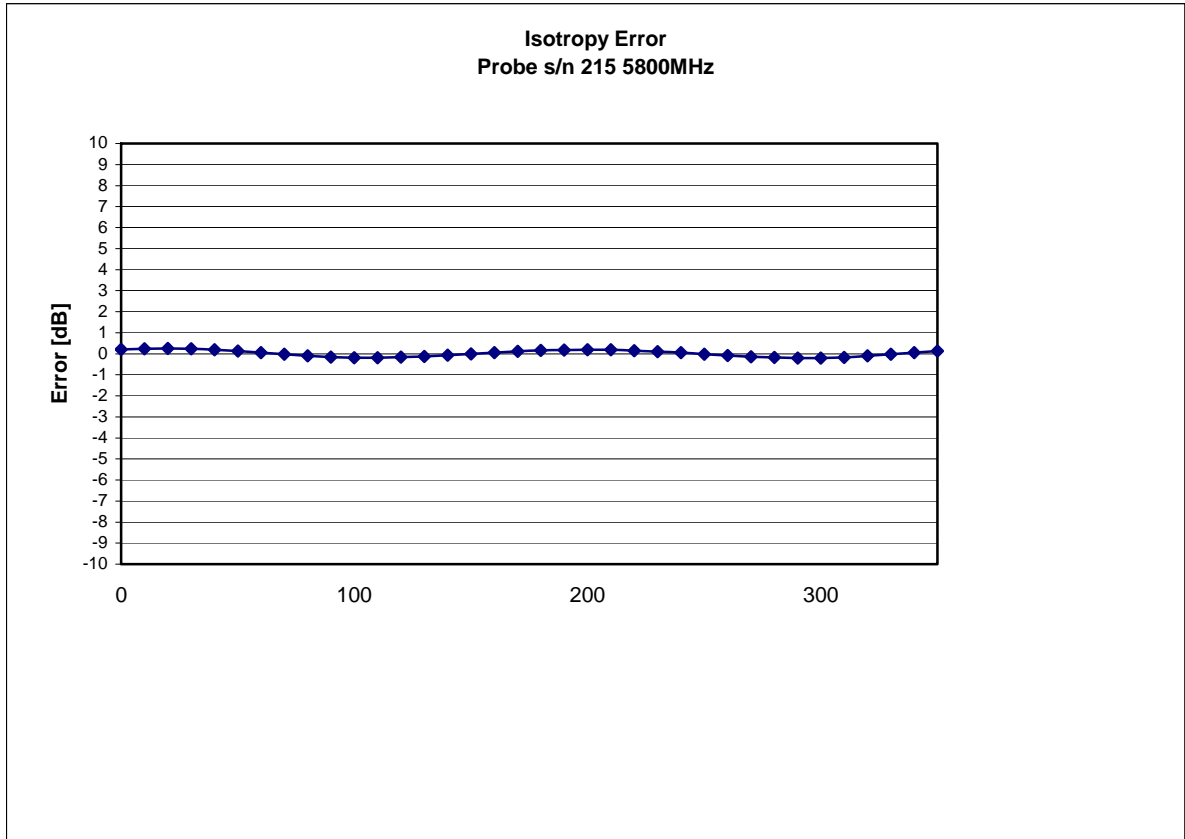
### **Spatial Resolution:**

The measured probe tip diameter is 5 mm (+/- 0.01 mm) and therefore meets the requirements of SSI/DRB-TP-D01-032 for spatial resolution.

## Receiving Pattern 5800 MHz (Air)



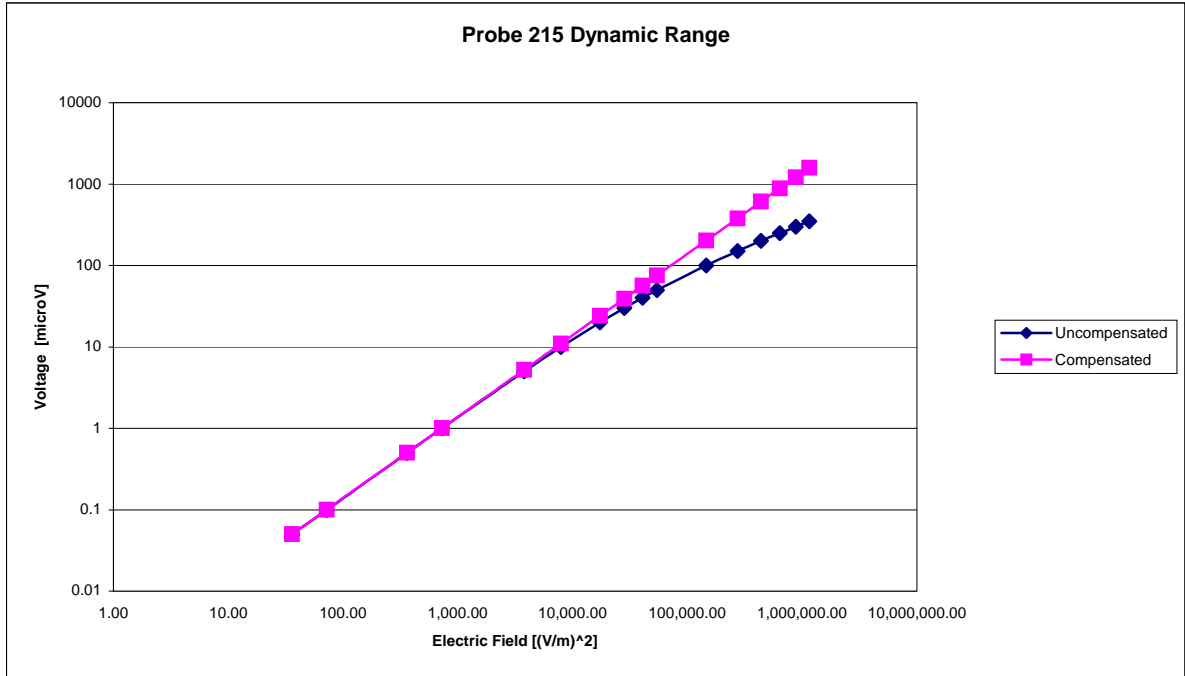
### Isotropy Error 5800 MHz (Air)



Isotropicity in Tissue:

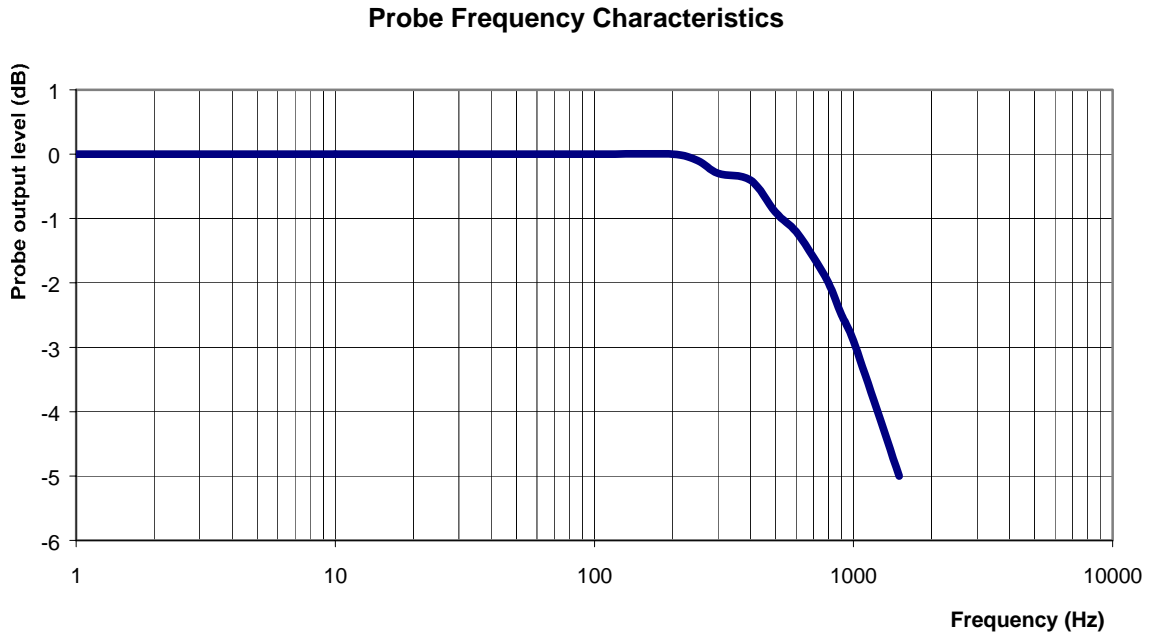
0.10 dB

## Dynamic Range





## Video Bandwidth



**Video Bandwidth at 500 Hz**                      1 dB  
**Video Bandwidth at 1.02 KHz:**                3 dB

## **Conversion Factor Uncertainty Assessment**

**Frequency:** 5800MHz

**Epsilon:** 49.6 (+/-5%)

**Sigma:** 6.25 S/m (+/-10%)

### **ConvF**

**Channel X:** 2.1 7%(K=2)

**Channel Y:** 2.1 7%(K=2)

**Channel Z:** 2.1 7%(K=2)

To minimize the uncertainty calculation all tissue sensitivity values were calculated using a load impedance of 5 M $\Omega$ .

### **Boundary Effect:**

For a distance of 2.4mm the evaluated uncertainty (increase in the probe sensitivity) is less than 2%.

## **Test Equipment**

The test equipment used during Probe Calibration, manufacturer, model number and, current calibration status are listed and located on the main APREL server R:\NCL\Calibration Equipment\Instrument List May 2005.

# NCL CALIBRATION LABORATORIES

Calibration File No.: CP-606

Client.: RFEL

## CERTIFICATE OF CALIBRATION

It is certified that the equipment identified below has been calibrated in the  
**NCL CALIBRATION LABORATORIES** by qualified personnel following recognized  
procedures and using transfer standards traceable to NRC/NIST.

Equipment: Miniature Isotropic RF Probe 2450 MHz

Manufacturer: APREL Laboratories

Model No.: E-020

Serial No.: 215

Calibration Procedure: SSI/DRB-TP-D01-032-E020-V2

Project No: RFEL-Probe-215-Calibration-5166

BODY Calibration

Calibrated: 10<sup>th</sup> June 2005  
Released on: 10<sup>th</sup> June 2005

This Calibration Certificate is Incomplete Unless Accompanied with the Calibration Results Summary

Released By: \_\_\_\_\_ Signature On File

**NCL** CALIBRATION LABORATORIES

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## **Introduction**

This Calibration Report reproduces the results of the calibration performed in line with the SSI/DRB-TP-D01-032-E020-V2 E-Field Probe Calibration Procedure. The results contained within this report are for APREL E-Field Probe E-020 215.

## **References**

SSI/DRB-TP-D01-032-E020-V2 E-Field Probe Calibration Procedure  
IEEE 1528 “Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body Due to Wireless Communications Devices: Experimental Techniques”  
SSI-TP-011 Tissue Calibration Procedure

## **Conditions**

Probe 215 was a new probe taken from stock prior to calibration.

**Ambient Temperature of the Laboratory:** 22 °C +/- 0.5°C  
**Temperature of the Tissue:** 21 °C +/- 0.5°C

**We the undersigned attest that to the best of our knowledge the calibration of this probe has been accurately conducted and that all information contained within this report has been reviewed for accuracy.**

-----  
**Stuart Nicol**  
**Director Product Development**

-----  
**Janusz Lokaj**  
**Member of Engineering Staff**  
**(Calibration Engineer)**

## Calibration Results Summary

<b>Probe Type:</b>	E-Field Probe E-020
<b>Serial Number:</b>	215
<b>Frequency:</b>	2450 MHz
<b>Sensor Offset:</b>	1.56 mm
<b>Sensor Length:</b>	2.5 mm
<b>Tip Enclosure:</b>	Ertalyte*
<b>Tip Diameter:</b>	<5 mm
<b>Tip Length:</b>	60 mm
<b>Total Length:</b>	290 mm

\*Resistive to recommended tissue recipes per IEEE-1528

## Sensitivity in Air

<b>Channel X:</b>	1.2 $\mu\text{V}/(\text{V}/\text{m})^2$
<b>Channel Y:</b>	1.2 $\mu\text{V}/(\text{V}/\text{m})^2$
<b>Channel Z:</b>	1.2 $\mu\text{V}/(\text{V}/\text{m})^2$
<b>Diode Compression Point:</b>	95 mV

## **Sensitivity in Body Tissue**

**Frequency:** 2450 MHz

**Epsilon:** 39.2 (+/-5%)                      **Sigma:** 1.80 S/m (+/-10%)

### **ConvF**

**Channel X:** 4.6

**Channel Y:** 4.6

**Channel Z:** 4.6

Tissue sensitivity values were calculated using the load impedance of the APREL Laboratories Daq-Paq.

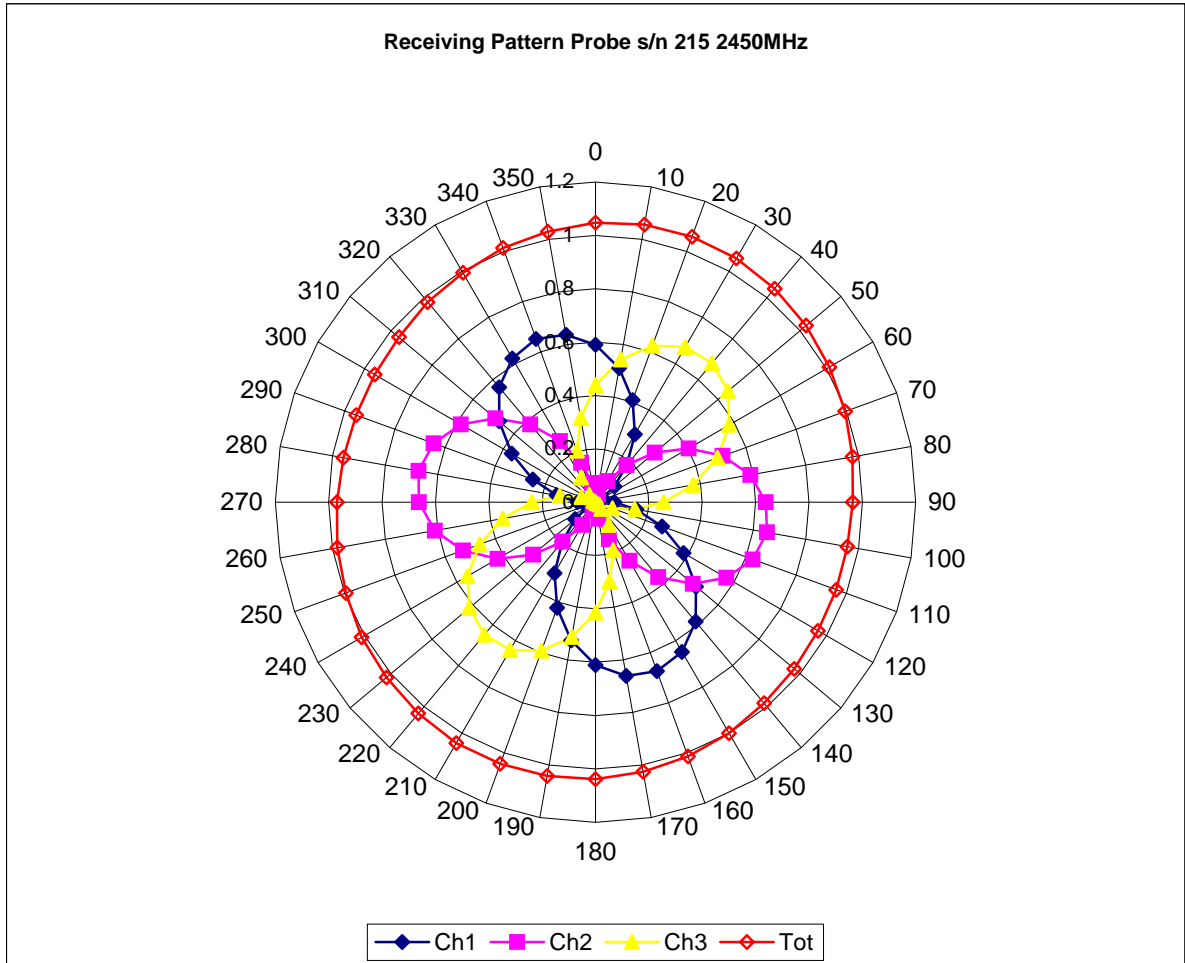
### **Boundary Effect:**

Uncertainty resulting from the boundary effect is less than 2% for the distance between the tip of the probe and the tissue boundary, when less than 2.44mm.

### **Spatial Resolution:**

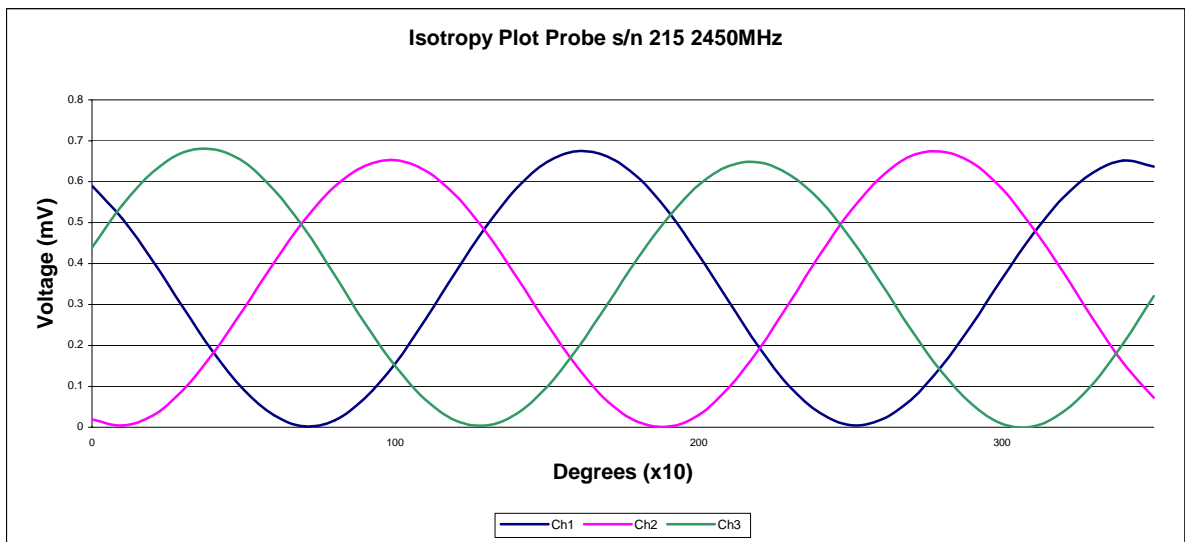
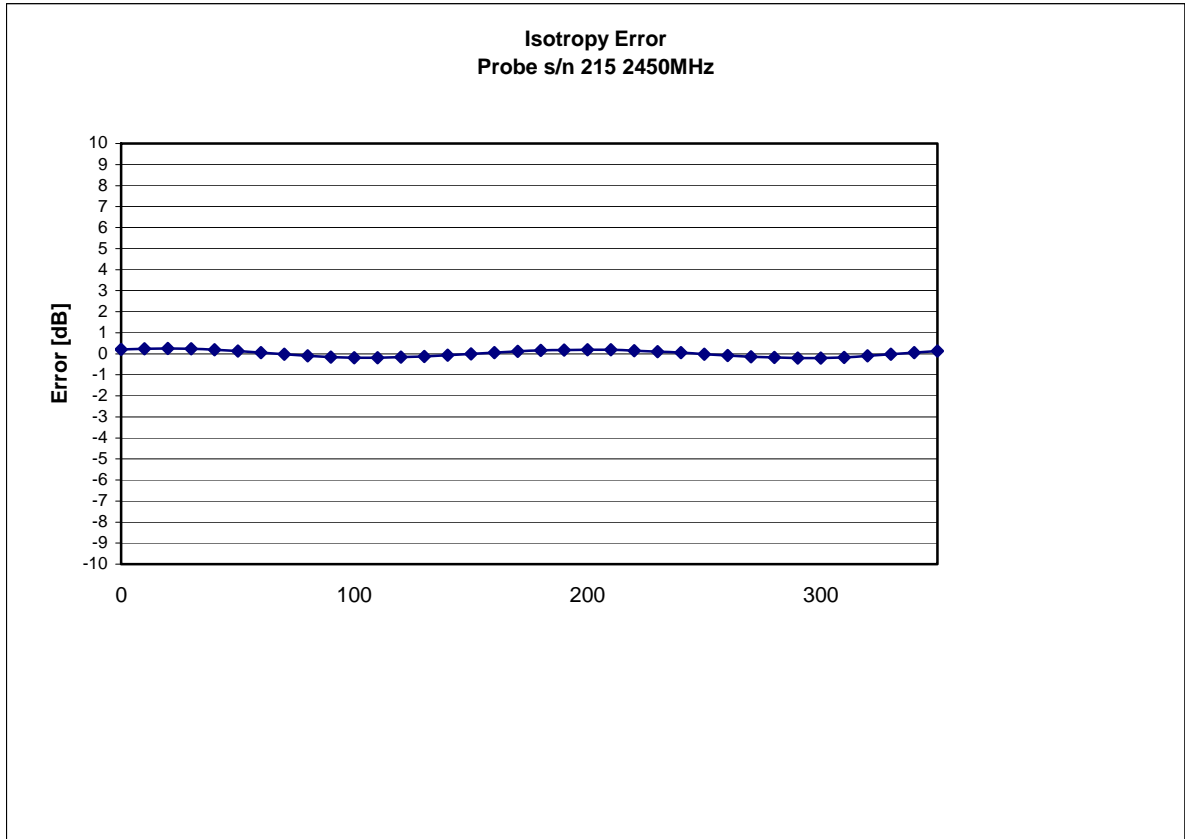
The measured probe tip diameter is 5 mm (+/- 0.01 mm) and therefore meets the requirements of SSI/DRB-TP-D01-032 for spatial resolution.

## Receiving Pattern 2450 MHz (Air)





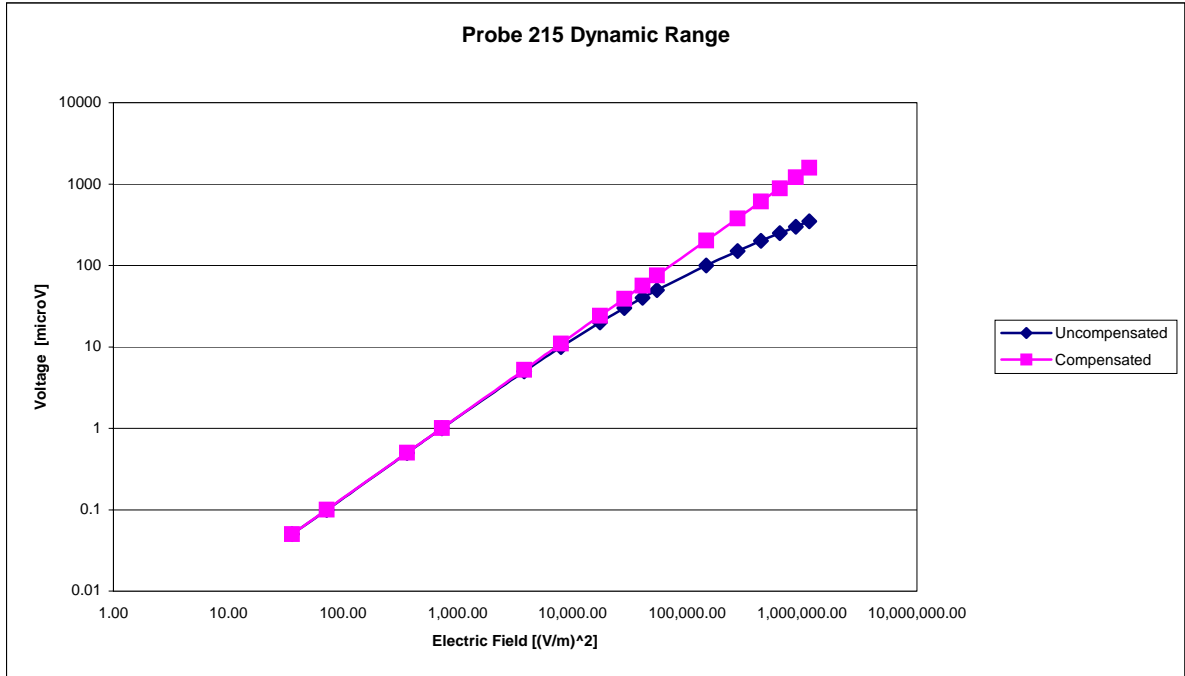
### Isotropy Error 2450 MHz (Air)



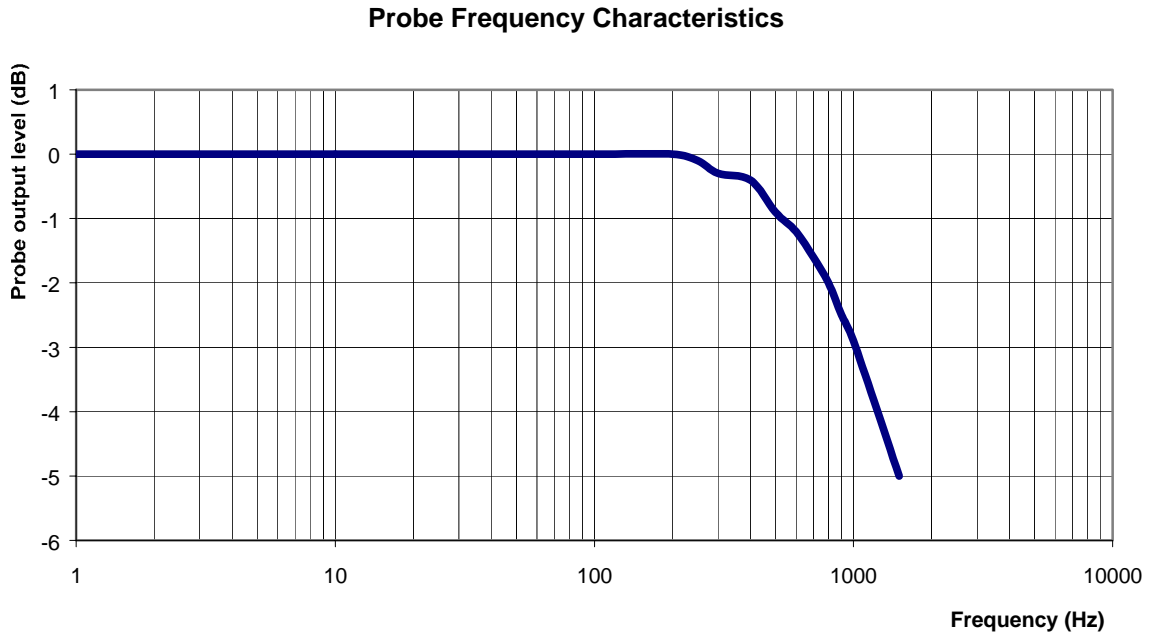
Isotropicity in Tissue:

0.10 dB

## Dynamic Range



## Video Bandwidth



**Video Bandwidth at 500 Hz**                      1 dB  
**Video Bandwidth at 1.02 KHz:**                3 dB

## **Conversion Factor Uncertainty Assessment**

**Frequency:** 2450MHz  
**Epsilon:** 39.2 (+/-5%)      **Sigma:** 1.80 S/m (+/-10%)

### **ConvF**

**Channel X:** 4.6      7%(K=2)

**Channel Y:** 4.6      7%(K=2)

**Channel Z:** 4.6      7%(K=2)

To minimize the uncertainty calculation all tissue sensitivity values were calculated using a load impedance of 5 MΩ.

### **Boundary Effect:**

For a distance of 2.4mm the evaluated uncertainty (increase in the probe sensitivity) is less than 2%.

## **Test Equipment**

The test equipment used during Probe Calibration, manufacturer, model number and, current calibration status are listed and located on the main APREL server R:\NCL\Calibration Equipment\Instrument List May 2005.

## Appendix E – Dipole Calibration Data Sheets

# NCL CALIBRATION LABORATORIES

Calibration File No: DC-591  
Project Number: RFEL-CAL-D-5258-5163

## CERTIFICATE OF CALIBRATION

It is certified that the equipment identified below has been calibrated in the  
**NCL CALIBRATION LABORATORIES** by qualified personnel following recognized  
procedures and using transfer standards traceable to NRC/NIST.

RFEL Validation Dipole

Manufacturer: APREL Laboratories

Part number: ALS-D-5258-S-2

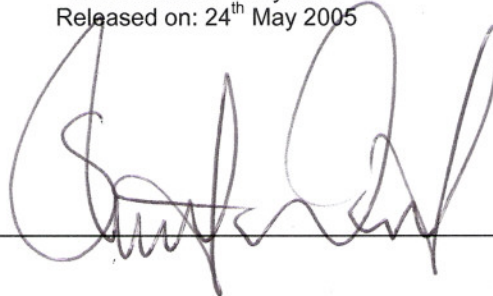
Frequency: 5.2GHz to 5.8GHz

Serial No: 5258-235-00801

Customer: RFEL

Calibrated: 24<sup>th</sup> May 2005  
Released on: 24<sup>th</sup> May 2005

Released By: \_\_\_\_\_

A handwritten signature in dark ink, appearing to be 'D. J. ...', is written over a horizontal line. The signature is stylized and somewhat cursive.

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FAX: (613) 820-4162

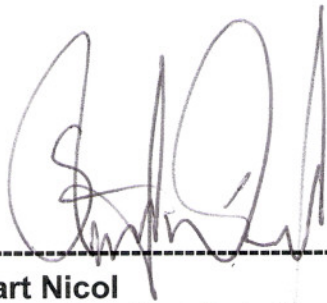
## Conditions

Dipole 5258-235-00801 was new and taken from stock prior to calibration.

**Ambient Temperature of the Laboratory:** 22 °C +/- 0.5°C

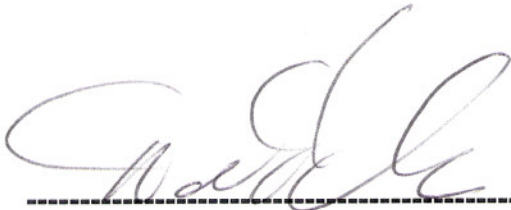
**Temperature of the Tissue:** 21 °C +/- 0.5°C

**We the undersigned attest that to the best of our knowledge the calibration of this device has been accurately conducted and that all information contained within this report has been reviewed for accuracy.**



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**Stuart Nicol**  
**Director Product Development**



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**D. Brooks**  
**Member of Engineering Staff**  
**(Calibration Engineer)**



## Calibration Results Summary

The following results relate the Calibrated Dipole and should be used as a quick reference for the user.

### Mechanical Dimensions

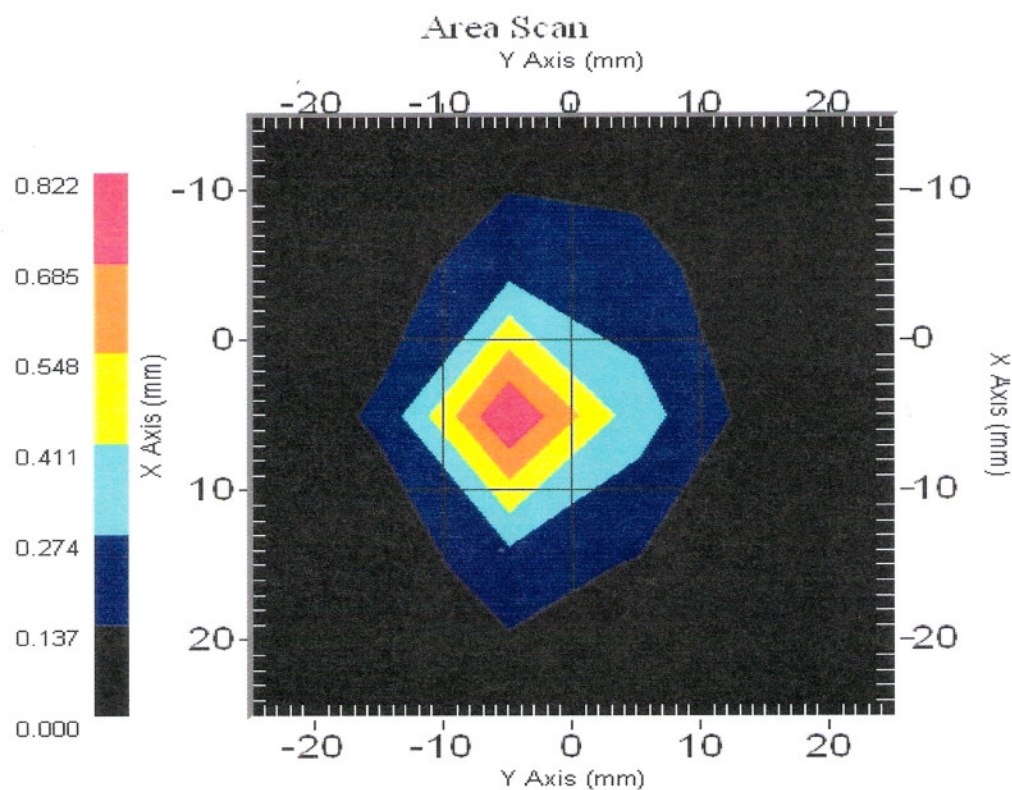
**Length:** 23.3 mm  
**Height:** 20.3 mm

### Electrical Specification

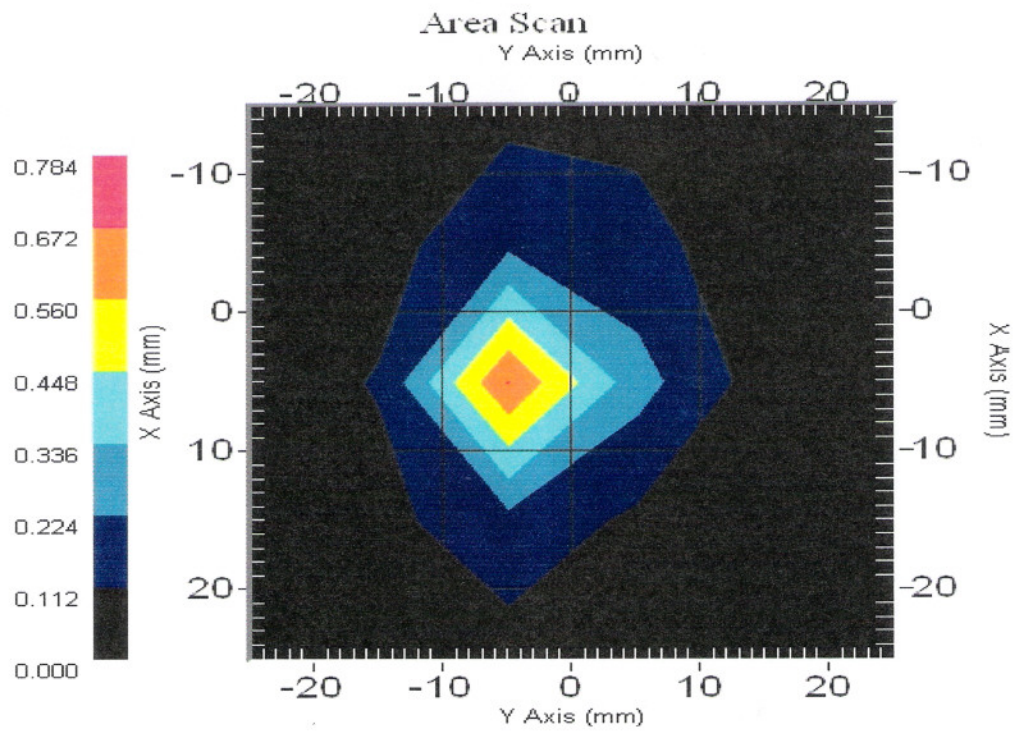
**SWR:** 1.22 U  
**Return Loss:** -20.0 dB  
**Impedance:** 50.0  $\Omega$

### System Validation Results

Frequency	1 Gram	10 Gram	Peak
5200 MHz	62.9	17.9	223.1



Frequency	1 Gram	10 Gram	Peak
5800 MHz	58.3	18	207.1



## **Introduction**

This Calibration Report has been produced in line with the SSI Dipole Calibration Procedure SSI-TP-018-ALSAS. The results contained within this report are for Validation Dipole 5258-235-00801. The calibration routine consisted of a three-step process. Step 1 was a mechanical verification of the dipole to ensure that it meets the mechanical specifications. Step 2 was an Electrical Calibration for the Validation Dipole, where the SWR, Impedance, and the Return loss were assessed. Step 3 involved a System Validation using the ALSAS-10U, along with APREL E-020 130 MHz to 26 GHz E-Field Probe Serial Number 212.

## **References**

SSI-TP-018-ALSAS Dipole Calibration Procedure  
SSI-TP-016 Tissue Calibration Procedure  
IEEE 1528 "Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body Due to Wireless Communications Devices: Experimental Techniques"

## **Conditions**

Dipole 5258-235-00801 was new taken from stock.

**Ambient Temperature of the Laboratory:** 22 °C +/- 0.5°C  
**Temperature of the Tissue:** 20 °C +/- 0.5°C

## Dipole Calibration Results

### Tissue Validation

Head Tissue 5200 MHz	Measured
Dielectric constant, $\epsilon_r$	35.3
Conductivity, $\sigma$ [S/m]	5.30

Head Tissue 5800 MHz	Measured
Dielectric constant, $\epsilon_r$	35.3
Conductivity, $\sigma$ [S/m]	5.30

### Mechanical Verification

APREL Length	APREL Height	Measured Length	Measured Height
23.1 mm	20.7 mm	23.3 mm	20.3 mm

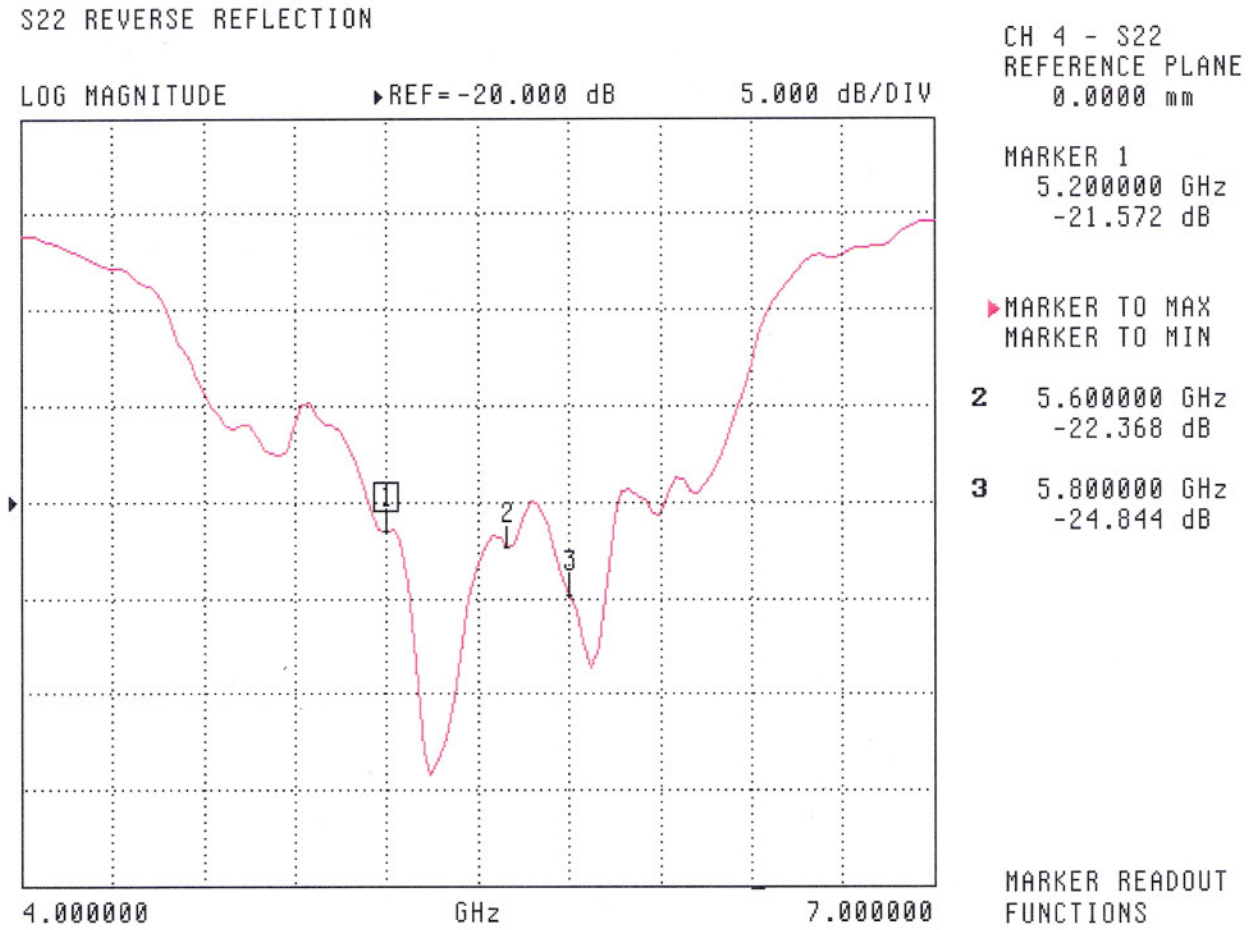
### Electrical Calibration

S11	5200MHz	5800MHz
RL (dB)	-21.6	-24.8
SWR	1.19	1.12
Impedance (ohms)	45.6	50.7



The Following Graphs are the results as displayed on the Vector Network Analyzer.

**S11 Parameter Return Loss**



**SWR**

S22 REVERSE REFLECTION

SWR                      ▶ REF=2.500 U                      500.000 mU/DIV



CH 4 - S22  
REFERENCE PLANE  
0.0000 mm

MARKER 1  
5.200000 GHz  
1.189 U

▶ MARKER TO MAX  
MARKER TO MIN

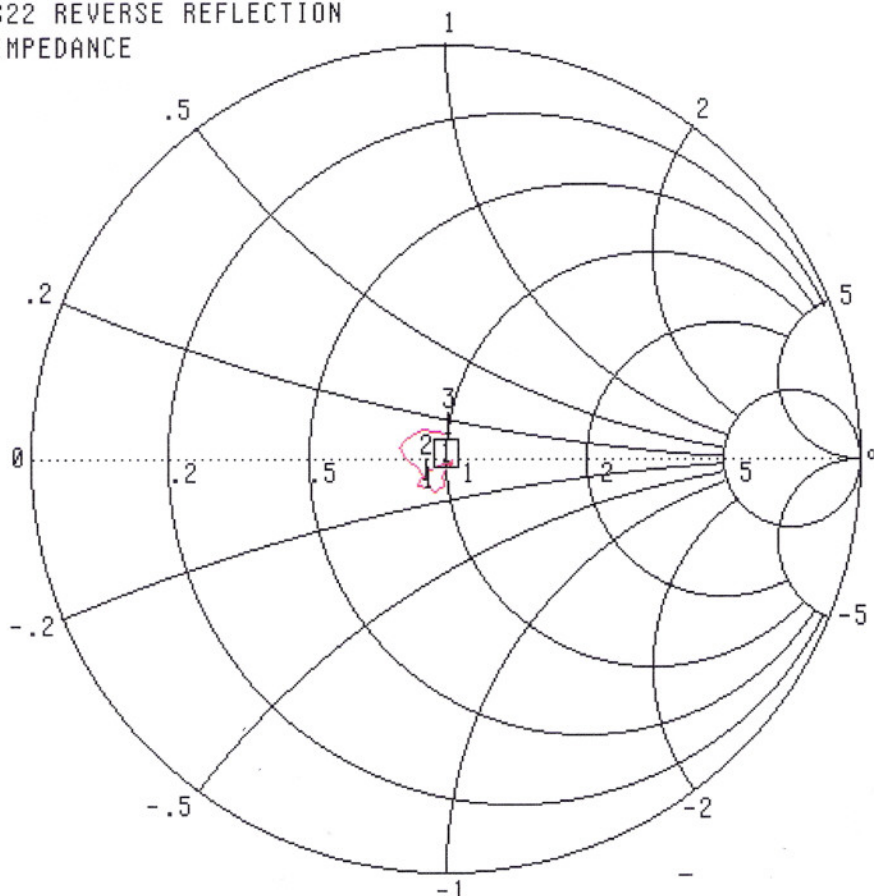
2 5.600000 GHz  
1.153 U

3 5.800000 GHz  
1.124 U

MARKER READOUT  
FUNCTIONS

### Smith Chart Dipole Impedance

S22 REVERSE REFLECTION  
IMPEDANCE



5.200000 - 5.800000 GHz

CH 4 - S22  
REFERENCE PLANE  
0.0000 mm

MARKER 1  
5.200000 GHz  
45.566  $\Omega$   
-6.839  $j\Omega$

▶ MARKER TO MAX  
MARKER TO MIN

2 5.600000 GHz  
45.348  $\Omega$   
-4.725  $j\Omega$   
3 5.800000 GHz  
50.691  $\Omega$   
5.736  $j\Omega$

MARKER READOUT  
FUNCTIONS

## **Test Equipment**

The test equipment used during Probe Calibration, manufacturer, model number and, current calibration status are listed and located on the main APREL server R:\NCL\Calibration Equipment\Instrument List May 2004



# NCL CALIBRATION LABORATORIES

Calibration File No: CD-342  
Project Number: RFEB-ALSAS-10U-4087

## CERTIFICATE OF CALIBRATION

It is certified that the equipment identified below has been calibrated in the  
**NCL CALIBRATION LABORATORIES** by qualified personnel following recognized  
procedures and using transfer standards traceable to NRC/NIST.

RFE Validation Dipole

Manufacturer: APREL Laboratories

Part number: ALS-D-2450-S-2

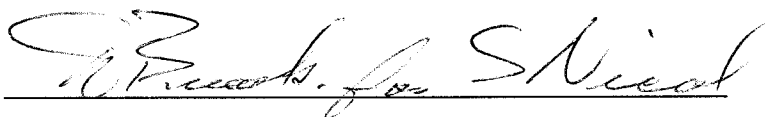
Frequency: 2.45 GHz

Serial No: RFE-278

Customer: RFE

Calibrated: 20 February 2004  
Released on: 20 February 2004

Released By:



*J. Brooks for S. Neal*

### **NCL** CALIBRATION LABORATORIES

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TEL: (613) 820-4988  
FAX: (613) 820-4161

## Calibration Results Summary

The following results relate the Calibrated Dipole and should be used as a quick reference for the user.

### Mechanical Dimensions

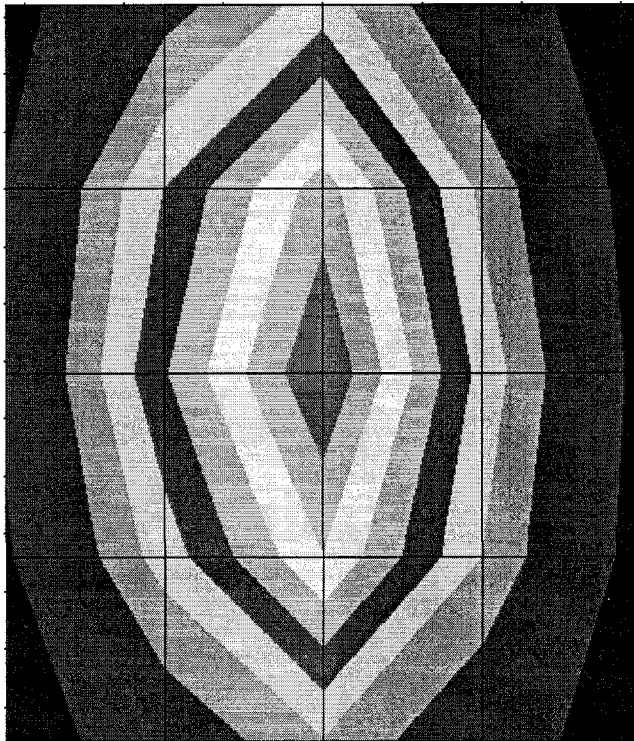
**Length:** 51.5 mm  
**Height:** 30.5 mm

### Electrical Specification

**SWR:** 1.09 U  
**Return Loss:** -26.8 dB  
**Impedance:** 49.0  $\Omega$

### System Validation Results

Frequency	1 Gram	10 Gram	Peak
2.45 GHz	48.07	25.65	95.6



## Introduction

This Calibration Report has been produced in line with the SSI Dipole Calibration Procedure SSI-TP-018-ALSAS. The results contained within this report are for Validation Dipole RFE-278. The calibration routine consisted of a three-step process. Step 1 was a mechanical verification of the dipole to ensure that it meets the IEEE/APREL mechanical specifications. Step 2 was an Electrical Calibration for the Validation Dipole, where the SWR, Impedance, and the Return loss were assessed. Step 3 involved a System Validation using the ALSAS-10U, along with Panasonic E-020 130 MHz to 26 GHz E-Field Probe Serial Number 213.

## References

SSI-TP-018-ALSAS Dipole Calibration Procedure

SSI-TP-016 Tissue Calibration Procedure

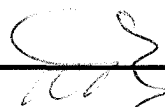
IEEE 1528 "Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body Due to Wireless Communications Devices: Experimental Techniques"

## Conditions

Dipole RFE-278 was new taken from stock.

**Ambient Temperature of the Laboratory:** 22 °C +/- 0.5°C

**Temperature of the Tissue:** 20 °C +/- 0.5°C



## Dipole Calibration Results

### Mechanical Verification

IEEE Length	IEEE Height	Measured Length	Measured Height
51.5 mm	30.4 mm	51.5 mm	30.5 mm

### Tissue Validation

Body Tissue 2450 MHz	Measured
Dielectric constant, $\epsilon_r$	52.5
Conductivity, $\sigma$ [S/m]	1.78

**Electrical Calibration**

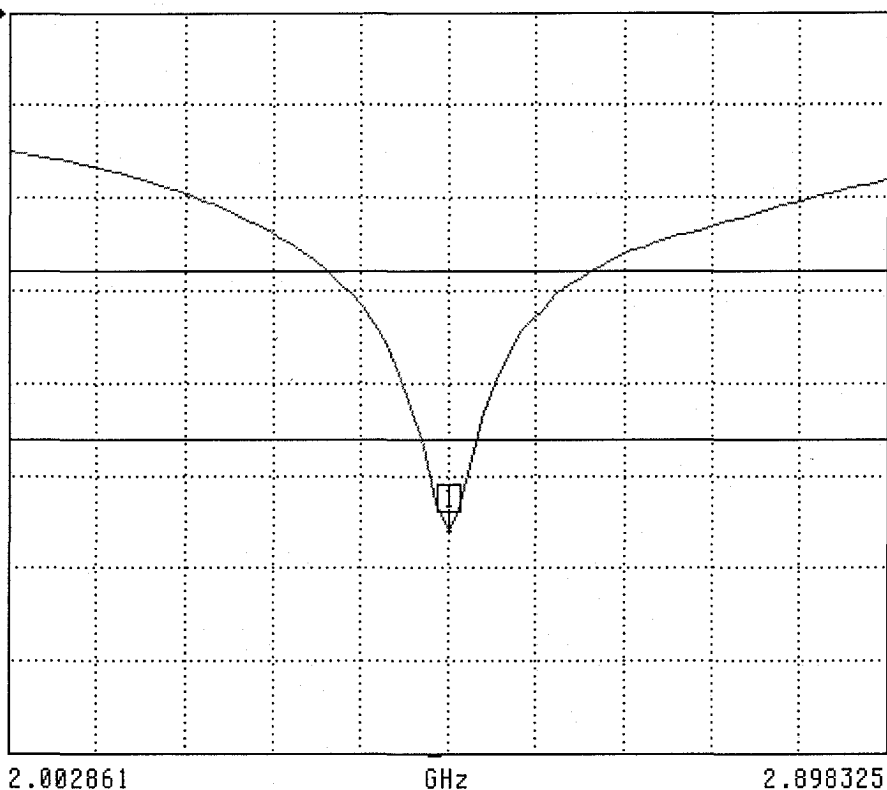
Test	Result
S11 R/L	-26.8 dB
SWR	1.098 U
Impedance	49.0 $\Omega$

The Following Graphs are the results as displayed on the Vector Network Analyzer.

**S11 Parameter Return Loss**

S11 FORWARD REFLECTION

LOG MAGNITUDE      ▶ REF=6.729 dB      6.000 dB/DIV



CH 1 - S11  
REFERENCE PLANE  
6.9844 mm

▶ MARKER 1  
2.450593 GHz  
-26.830 dB

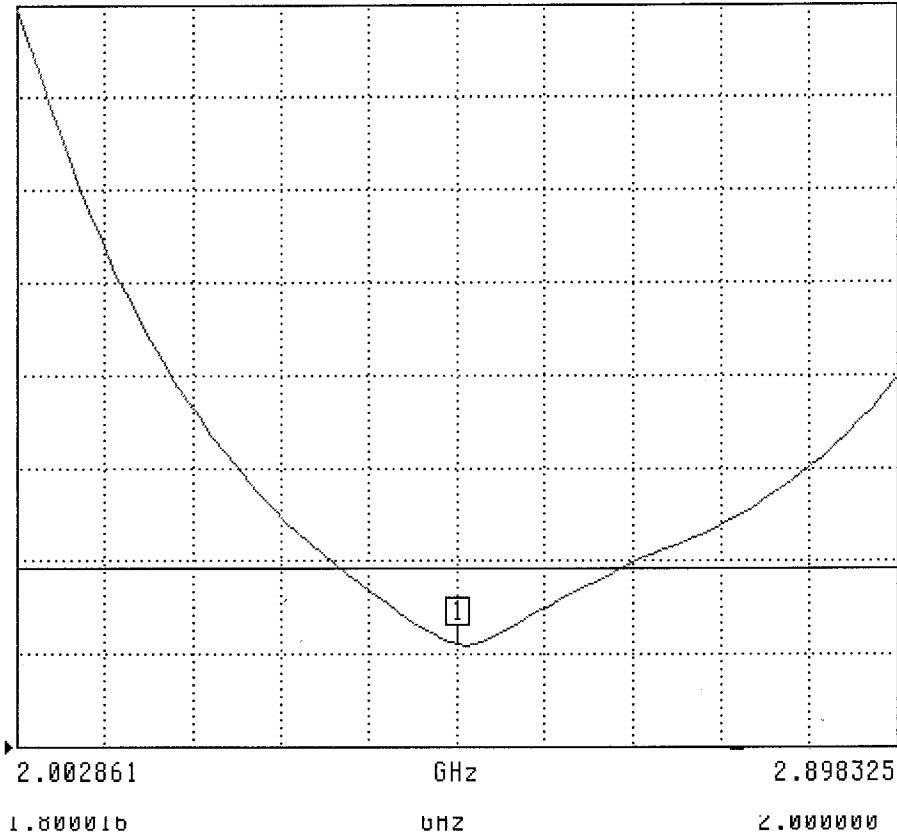
MARKER TO MAX  
MARKER TO MIN

MARKER READOUT  
FUNCTIONS

SWR

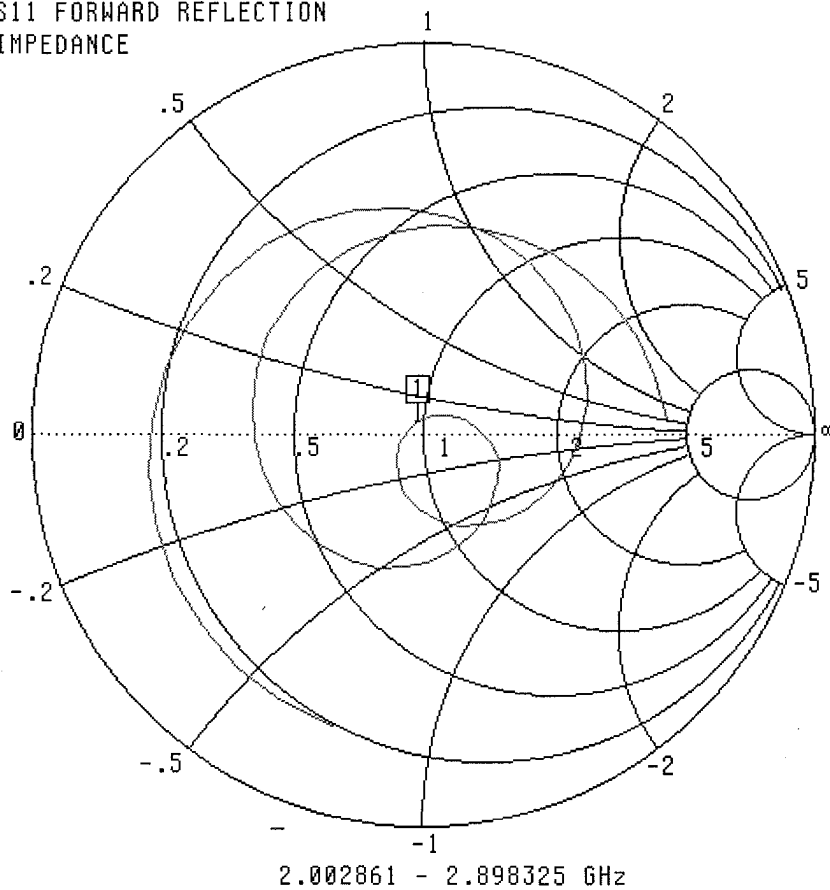
S11 FORWARD REFLECTION

SWR      ▶ REF=0.000 pU      1.000 U/DIV



### Smith Chart Dipole Impedance

S11 FORWARD REFLECTION  
IMPEDANCE



CH 1 - S11  
REFERENCE PLANE  
6.9844 mm

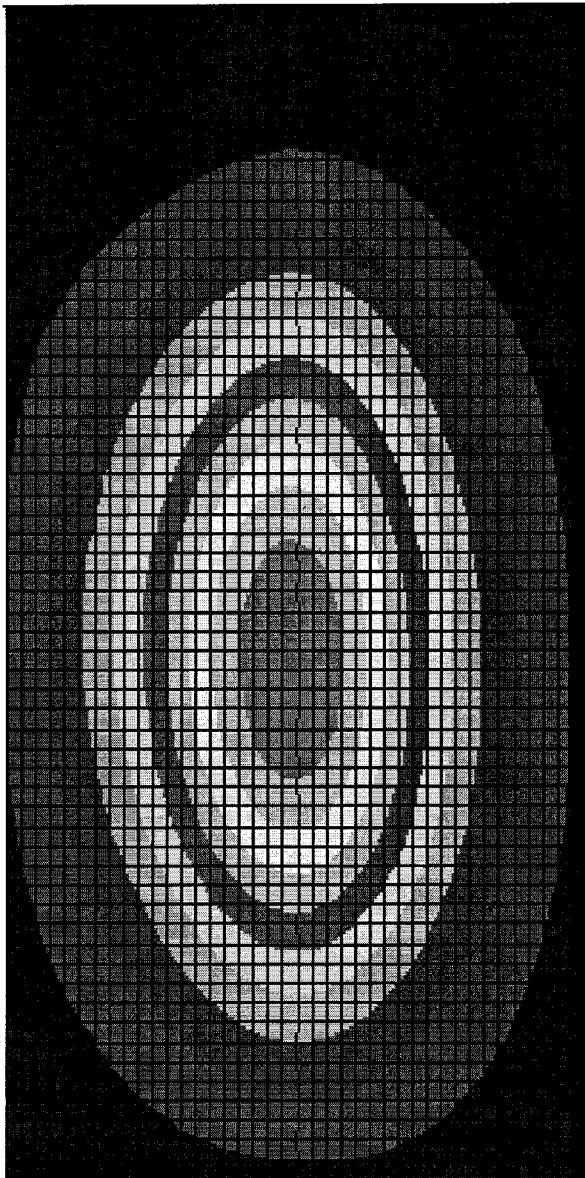
▶ MARKER 1  
2.450593 GHz  
49.037 Ω  
2.877 jΩ

MARKER TO MAX  
MARKER TO MIN

MARKER READOUT  
FUNCTIONS

**System Validation Results Using the Electrically Calibrated Dipole**

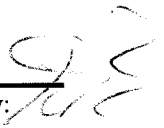
Frequency	1 Gram	10 Gram	Peak Above Feed Point
2.45 GHz	48.07	25.65	95.6





## Test Equipment

The test equipment used during Probe Calibration, manufacturer, model number and, current calibration status are listed and located on the main APREL server R:\NCL\Calibration Equipment\Instrument List May 2003



## Appendix F – Phantom Calibration Data Sheets

## NCL CALIBRATION LABORATORIES

Calibration File No.: RFE-273

# CERTIFICATE OF CALIBRATION

It is certified that the equipment identified below has been calibrated in the **NCL CALIBRATION LABORATORIES** by qualified personnel following recognized procedures and using transfer standards traceable to National Standards.

Thickness of the UniPhantom is 2 mm  $\pm$  10%  
Pinna thickness is 6 mm  $\pm$  10%

Resolution:	0.01 mm	Calibrated to:	0.0 mm
Stability:	OK	Accuracy:	< 0.1 mm

Calibrated By: Karen K. Feb 17/04.

### **NCL** CALIBRATION LABORATORIES

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