

# NCL CALIBRATION LABORATORIES

Calibration File No.: PC 1432

Client.: IAC

## 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

Record of Calibration

Head and Body

Manufacturer: APREL Laboratories

**Model No.:** E-020

**Serial No.:** 500-00273

**Calibration Procedure:** D01-032-E020-V2, D22-012-Tissue, D28-002-Dipole

**Project No:** ISL-E020-5612

**Calibrated:** 1<sup>st</sup> October 2012

**Released on:** 5<sup>th</sup> October 2012

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

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



Art Brennan, Quality Manager

**NCL** CALIBRATION LABORATORIES

303 Terry Fox Drive, Suite 102  
Kanata, Ontario  
CANADA K2K 3J1

Division of APREL  
TEL: (613) 435-8300  
FAX: (613) 435-8306

### Introduction

This Calibration Report reproduces the results of the calibration performed in line with the references listed below. Calibration is performed using accepted methodologies as per the references listed below. Probes are calibrated for air, and tissue and the values reported are the results from the physical quantification of the probe through meteorological practices.

### Calibration Method

Probes are calibrated using the following methods.

<1000MHz

TEM Cell for sensitivity in air

Standard phantom using temperature transfer method for sensitivity in tissue

>1000MHz

Waveguide\* method to determine sensitivity in air and tissue

\*Waveguide is numerically (simulation) assessed to determine the field distribution and power

The boundary effect for the probe is assessed using a standard flat phantom where the probe output is compared against a numerically simulated series of data points

### References

- IEEE Standard 1528 (2003) including Amendment 1  
IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques
- EN 62209-1 (2006)  
Human Exposure to RF Fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures-Part 1: Procedure to measure the Specific Absorption Rate (SAR) for hand-held mobile wireless devices
- IEC 62209-2 Ed. 1.0 (2010-03)  
Human exposure to RF fields from hand-held and body-mounted wireless devices - Human models, instrumentation, and procedures - Part 2: specific absorption rate (SAR) for wireless communication devices (30 MHz - 6 GHz)
- TP-D01-032-E020-V2 E-Field probe calibration procedure
- D22-012-Tissue dielectric tissue calibration procedure
- D28-002-Dipole procedure for validation of SAR system using a dipole
- IEEE 1309 Draft Standard for Calibration of Electromagnetic Field Sensors and Probes, Excluding Antennas, from 9kHz to 40GHz

## NCL Calibration Laboratories

Division of APREL Inc.

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### Conditions

Probe 500-00273 was a recalibration.

\*\*The probe was received in good working order, although at 1900MHz the uncertainty was higher than our standard (see note\*\*)

**Ambient Temperature of the Laboratory:** 22 °C +/- 1.5°C  
**Temperature of the Tissue:** 21 °C +/- 1.5°C  
**Relative Humidity:** < 60%

### Primary Measurement Standards

Instrument	Serial Number	Cal due date
Power meter Anritsu MA2408A	90025437	Nov.4, 2011
Power Sensor Anritsu MA2481D	103555	Nov 4, 2011
Attenuator HP 8495A (70dB)	1944A10711	Sept. 14, 2011
Network Analyzer Anritsu MT8801C	MB11855	Feb. 8, 2012

### Secondary Measurement Standards


Signal Generator Agilent E4438C -506 MY55182336 June 7, 2012

### Attestation

The below named signatories have conducted the calibration and review of the data which is presented in this calibration report.

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

  
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**Art Brennan, Quality Manager**

  
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**Dan Brooks, Test Engineer**

**Probe Summary**

<b>Probe Type:</b>	E-Field Probe E020
<b>Serial Number:</b>	500-00273
<b>Frequency:</b>	As presented on page 5
<b>Sensor Offset:</b>	1.56
<b>Sensor Length:</b>	2.5
<b>Tip Enclosure:</b>	Composite*
<b>Tip Diameter:</b>	< 2.9 mm
<b>Tip Length:</b>	55 mm
<b>Total Length:</b>	289 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

## NCL Calibration Laboratories

Division of APREL Inc.

### Calibration for Tissue (Head H, Body B)

Frequency	Tissue Type	Measured Epsilon	Measured Sigma	Calibration Uncertainty	Tolerance Uncertainty for 5%*	Conversion Factor
450 H	Head	X	X	X	X	X
450 B	Body	X	X	X	X	X
750 H	Head	X	X	X	X	X
750 B	Body	X	X	X	X	X
850 H	Head	42.86	0.95	3.5	3.4	6.5
850 B	Body	53.71	1.04	3.5	3.4	6.4
900 H	Head	41.5	0.99	3.5	3.4	6.1
900 B	Body	53.25	1.04	3.5	3.4	6.3
1450 H	Head	X	X	X	X	X
1450 B	Body	X	X	X	X	X
1500 H	Head	X	X	X	X	X
1500 B	Body	X	X	X	X	X
1640 H	Head	X	X	X	X	X
1640 B	Body	X	X	X	X	X
1750 H	Head	X	X	X	X	X
1750 B	Body	X	X	X	X	X
1800 H	Head	36.85	1.35	3.5	2.7	5.5
1800 B	Body	52.38	1.5	3.5	2.7	5.4
1900 H	Head	38.21	1.46	3.5	2.7	5.7
1900 B	Body	52.1	1.59	3.5	2.7	5.4
2000 H	Head	X	X	X	X	X
2000 B	Body	X	X	X	X	X
2100 H	Head	39.8	1.49	3.5	2.9	5.0
2100 B	Body	53.0	1.58	3.5	2.9	4.9
2300 H	Head	X	X	X	X	X
2300 B	Body	X	X	X	X	X
2450 H	Head	38.2	1.84	3.5	3.5	4.65
2450B	Body	50.63	1.99	3.5	3.5	4.4
2600 H	Head	X	X	X	X	X
2600 B	Body	X	X	X	X	X
3000 H	Head	X	X	X	X	X
3000 B	Body	X	X	X	X	X
3600 H	Head	X	X	X	X	X
3600 B	Body	X	X	X	X	X
5200 H	Head	X	X	X	X	X
5200 B	Body	X	X	X	X	X
5600 H	Head	X	X	X	X	X
5600 B	Body	X	X	X	X	X
5800 H	Head	X	X	X	X	X
5800 B	Body	X	X	X	X	X

### **Boundary Effect:**

Uncertainty resulting from the boundary effect is less than 2.1% for the distance between the tip of the probe and the tissue boundary, when less than 0.58mm.

### **Spatial Resolution:**

The spatial resolution uncertainty is less than 1.5% for 4.9mm diameter probe.

The spatial resolution uncertainty is less than 1.0% for 2.5mm diameter probe.

### **DAQ-PAQ Contribution**

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 0.58mm the worst case evaluated uncertainty (increase in the probe sensitivity) is less than 2.1%.

### **NOTES:**

\*The maximum deviation from the centre frequency when comparing the lower to upper range is listed.

\*\*1800MHz Head was evaluated at close to the 10% allowable deviation; the deviation has now been normalized to within 2%.

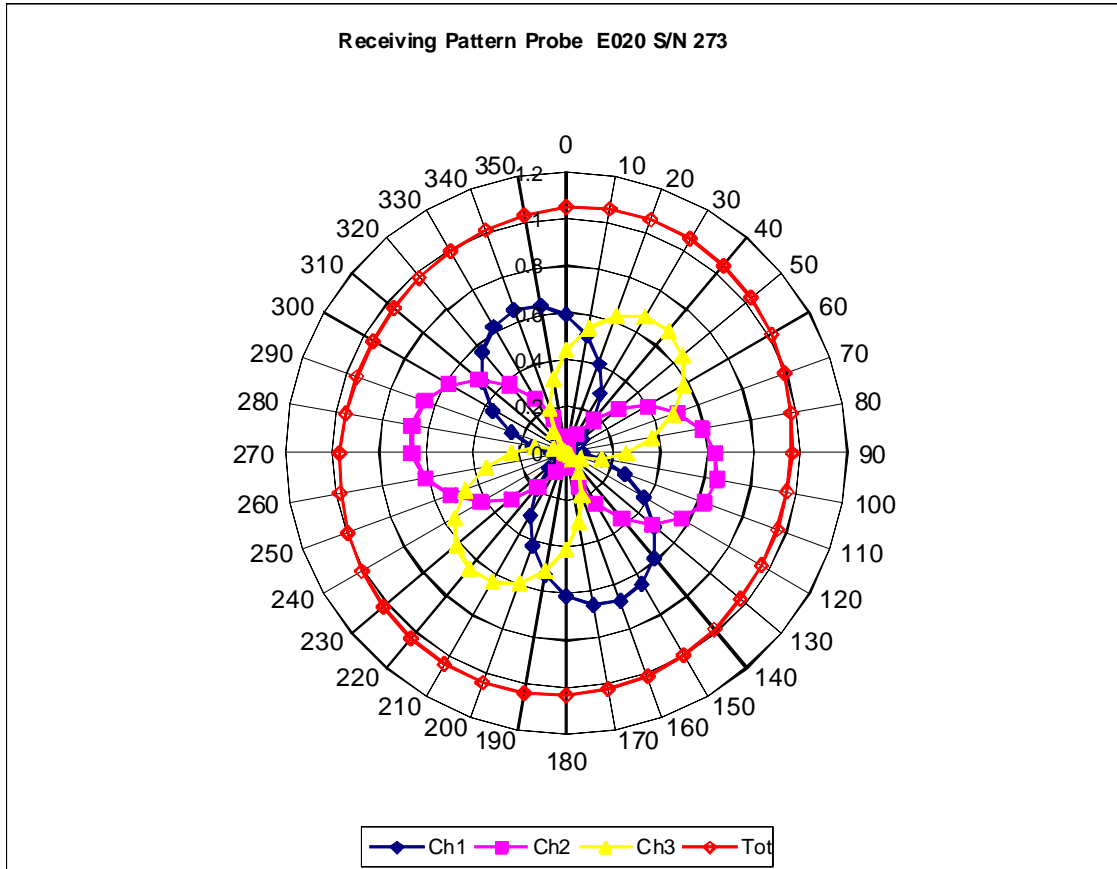
\*\*\*1800MHz Body was evaluated at close to the 10% allowable deviation; the deviation has now been normalized to within 2%.

\*\*\*\*1900MHz Body was evaluated at close to the 10% allowable deviation; the deviation has now been normalized to within 2%.

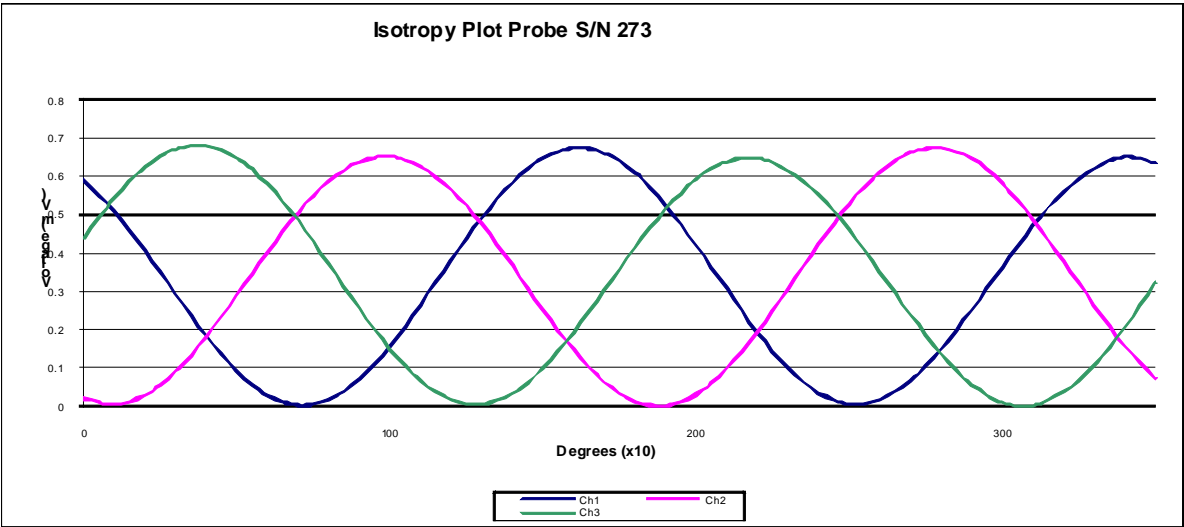
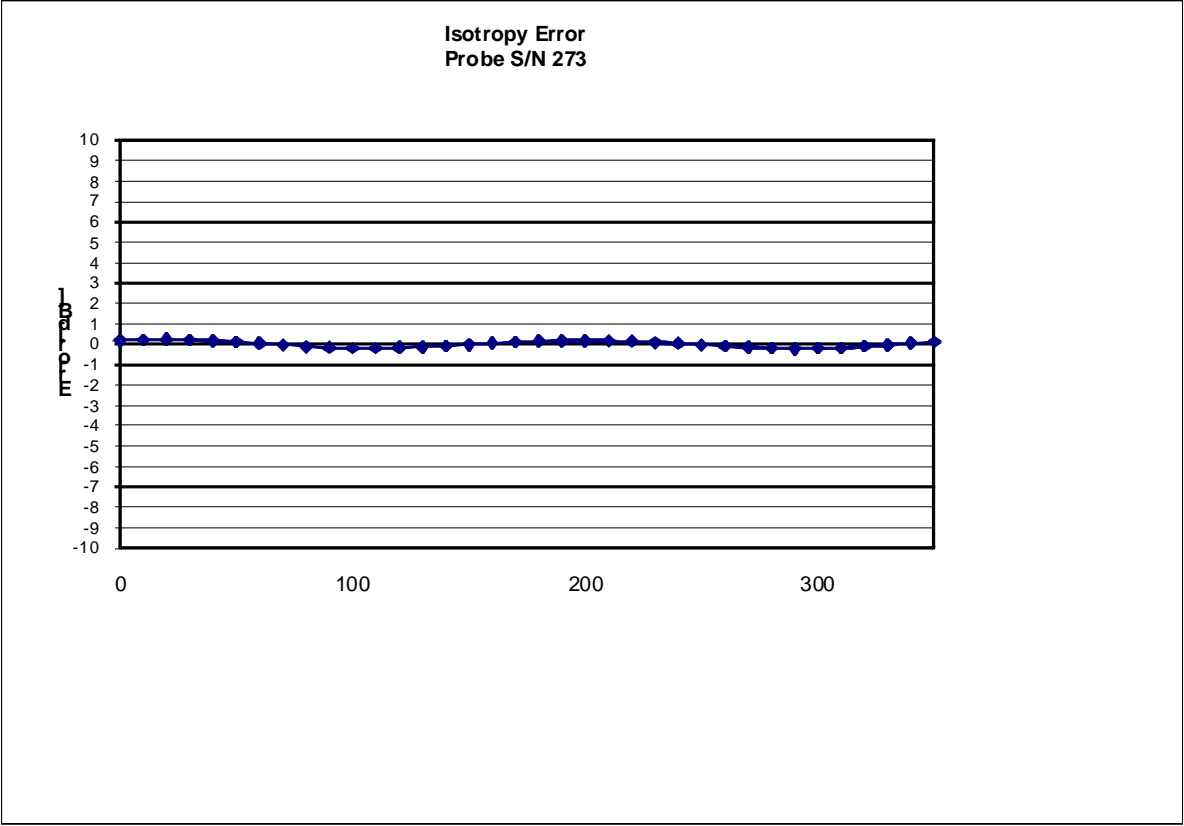
\*\*\*\*\*2450MHz Head was evaluated at close to the 10% allowable deviation; the deviation has now been normalized to within 2%.

\*\*\*\*\*2450MHz Body was evaluated at close to the 10% allowable deviation; the deviation has now been normalized to within 2%.

## Receiving Pattern Air



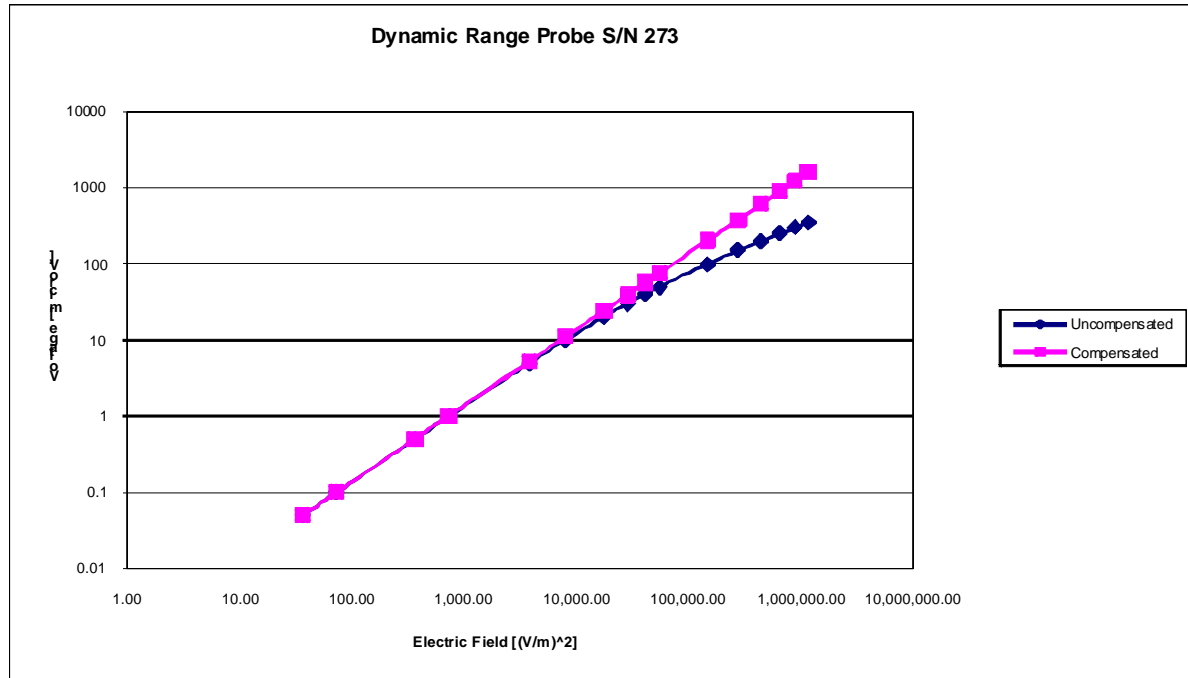
Isotropy Error Air



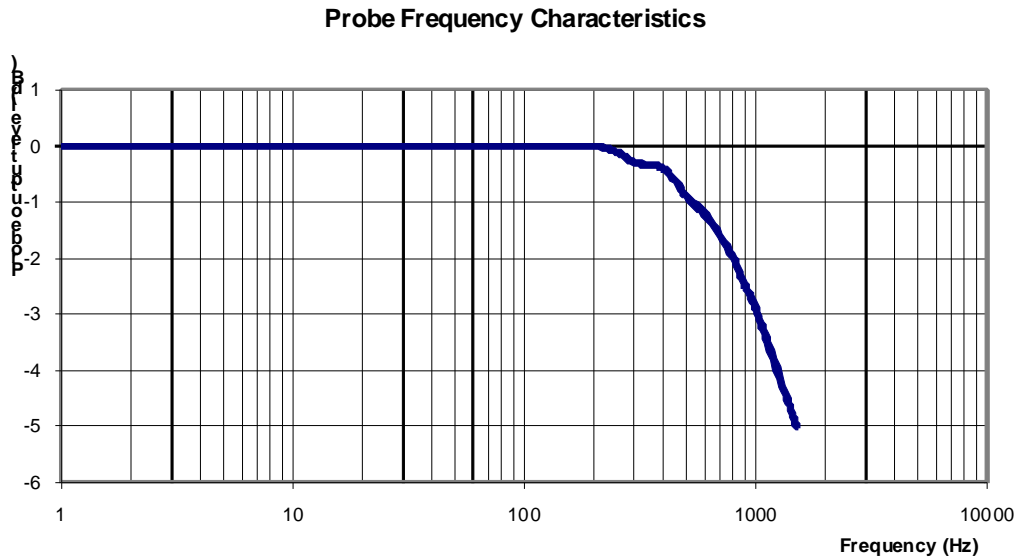
Isotropy Tissue:

0.10 dB

## Dynamic Range



## Video Bandwidth



<b>Video Bandwidth at 500 Hz</b>	<b>1 dB</b>
<b>Video Bandwidth at 1.02 KHz:</b>	<b>3 dB</b>

## 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 2012.

# NCL CALIBRATION LABORATORIES

Calibration File No: DC-1217/18  
Project Number: SGL-IAC-DC-5582-93

## 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.

Validation Dipole  
835MHz Head & Body

Manufacturer: APREL Laboratories

Part number: ALS-D-835-S-2

Frequency: 835MHz

Serial No: 180-00556

Customer: IAC

Calibrated: 17<sup>th</sup> May 2011  
Released on: 27<sup>th</sup> May 2011

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

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

**NCL** CALIBRATION LABORATORIES

303 Terry Fox Drive, Suite 102  
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TEL: (613) 435-8300  
FAX: (613) 435-8306

## Conditions

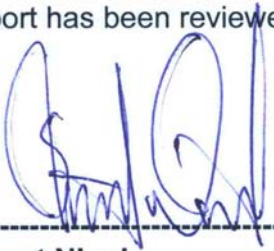
Dipole 180-00556 was a re-calibration.

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

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

Dipoles are calibrated on the ALSAS-10U with a feed power normalized to 1Watt.

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.



Stuart Nicol



C. Teodorian

## Primary Measurement Standards

Instrument	Serial Number	Cal due date
Power meter Anritsu MA2408A	90025437	Nov.4, 2010
Power Sensor Anritsu MA2481D	103555	Nov 4, 2010
Attenuator HP 8495A (70dB)	1944A10711	Sept. 14, 2010
Network Analyzer Anritsu MT8801C	MB11855	Feb. 8, 2011

## Secondary Measurement Standards

Signal Generator Agilent E4438C -506	MY55182336	June 7, 2011
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## Calibration Results Summary

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

### Mechanical Dimensions

**Length:** 161.0 mm  
**Height:** 89.8 mm

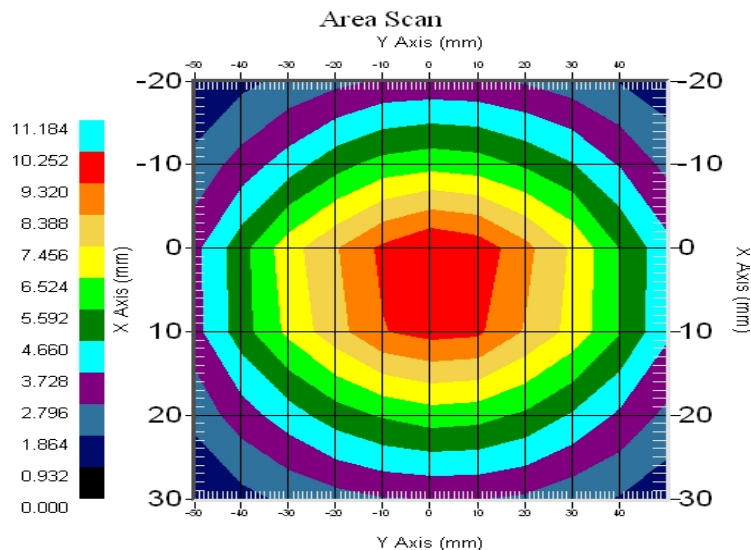
### Electrical Specification 835MHz

Tissue Type	Return Loss:	Impedance:	SWR:
Head	-26.655	51.666	1.102U
Body	-22.106	57.482	1.177U

### System Validation Results

Tissue	Frequency	1 Gram	10 Gram	Peak
Head	835 MHz	9.590	6.003	15.013
Body	835 MHz	9.981	6.006	15.013

### 835MHz



## 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 180-00556. 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-030 130 MHz to 26 GHz E-Field Probe Serial Number 215.

## References

- IEEE Standard 1528 (2003) including Amendment 1  
IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques
- EN 62209-1 (2006)  
Human Exposure to RF Fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures-Part 1: Procedure to measure the Specific Absorption Rate (SAR) for hand-held mobile wireless devices
- IEC 62209-2 Ed. 1.0 (2010-03)  
Human exposure to RF fields from hand-held and body-mounted wireless devices - Human models, instrumentation, and procedures - Part 2: specific absorption rate (SAR) for wireless communication devices (30 MHz - 6 GHz)
- TP-D01-032-E020-V2 E-Field probe calibration procedure
- D22-012-Tissue dielectric tissue calibration procedure
- D28-002-Dipole procedure for validation of SAR system using a dipole
- IEEE 1309 Draft Standard for Calibration of Electromagnetic Field Sensors and Probes, Excluding Antennas, from 9kHz to 40GHz

## Conditions

Dipole 180-00556 was a re-calibration.

<b>Ambient Temperature of the Laboratory:</b>	22 °C +/- 0.5°C
<b>Temperature of the Tissue:</b>	20 °C +/- 0.5°C

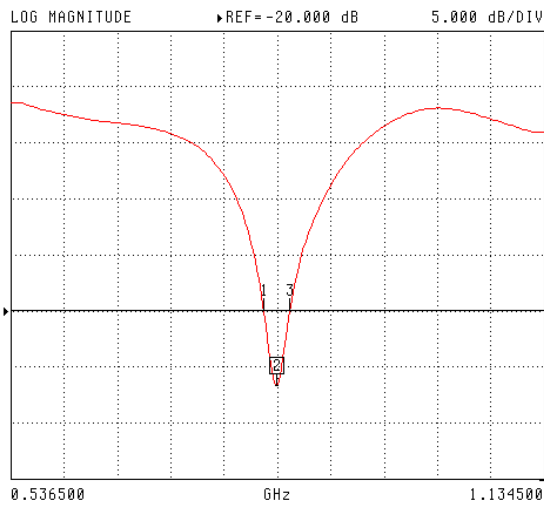
## Electrical Calibration

### Electrical Specification 835MHz

Tissue Type	Measured Epsilon	Measured Sigma
Head	41.09	0.89
Body	53.15	0.95

#### Head Tissue

S11 FORWARD REFLECTION



CH 1 - S11  
5.0584 mm REF  
0.000 dB OFFSET  
0.00° OFFSET

MARKER 2  
0.835000 GHz  
-26.655 dB

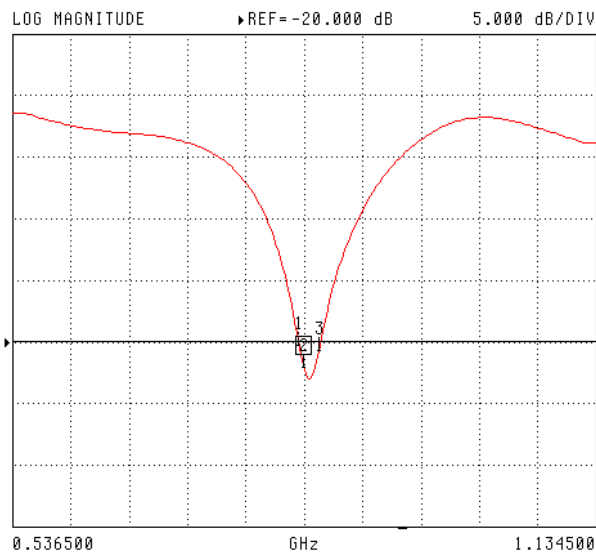
MARKER TO MAX  
MARKER TO MIN

1 0.820034 GHz  
-20.001 dB  
3 0.849726 GHz  
-20.001 dB

MARKER READOUT  
FUNCTIONS

#### Body Tissue

S11 FORWARD REFLECTION



CH 1 - S11  
5.0584 mm REF  
0.000 dB OFFSET  
0.00° OFFSET

MARKER 2  
0.835000 GHz  
-22.106 dB

MARKER TO MAX  
MARKER TO MIN

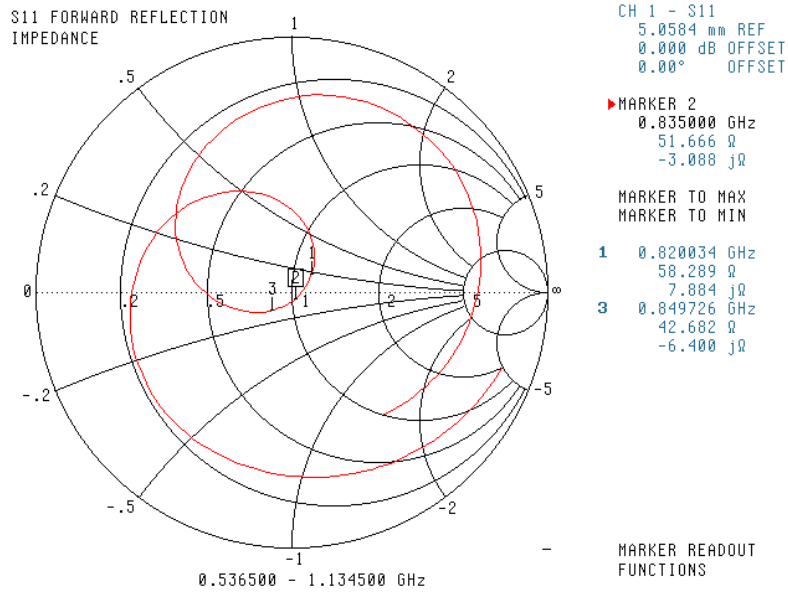
1 0.830132 GHz  
-20.270 dB  
3 0.850690 GHz  
-20.742 dB

MARKER READOUT  
FUNCTIONS

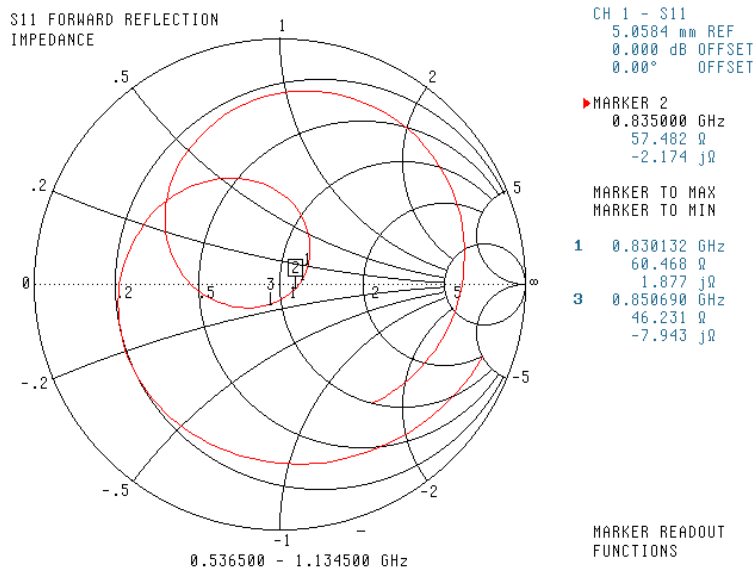
## Electrical Specification 835MHz Impedance

Tissue Type	Measured Epsilon	Measured Sigma
Head	41.09	0.89
Body	53.15	0.95

### Head Tissue



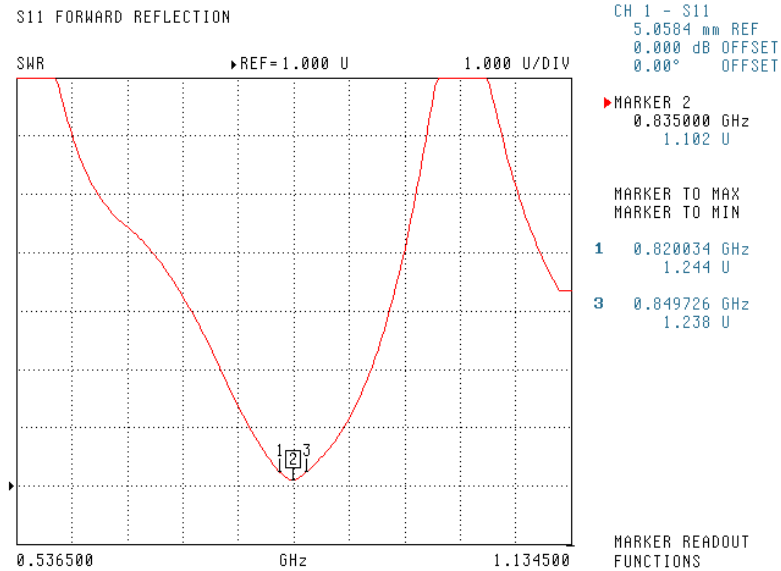
### Body Tissue



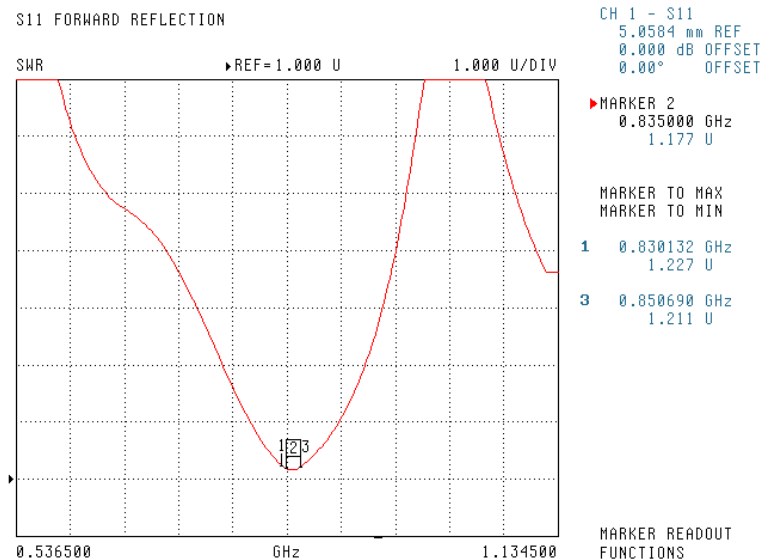
## Electrical Specification 835MHz Standing Wave Ratio

Tissue Type	Measured Epsilon	Measured Sigma
Head	41.09	0.89
Body	53.15	0.95

### Head Tissue



### Body Tissue



## **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 2011.

# NCL CALIBRATION LABORATORIES

Calibration File No: DC-1224/5  
Project Number: SGL-IAC-DC-5582-93

## C E R T I F I C A T E   O F   C A L I B R A T I O N

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.

Validation Dipole  
1900MHz Head & Body

Manufacturer: APREL Laboratories

Part number: ALS-D-1900-S-2

Frequency: 1900MHz

Serial No: 210-00707

Customer: IAC

Calibrated: 16<sup>th</sup> May 2011  
Released on: 27<sup>th</sup> May 2011

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

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

**NCL** CALIBRATION LABORATORIES

303 Terry Fox Drive, Suite 102  
Kanata, Ontario  
CANADA K2K 3J1

Division of APREL  
TEL: (613) 435-8300  
FAX: (613) 435-8306

## Conditions

Dipole 210-00707 was a new dipole taken from stock.

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

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

Dipoles are calibrated on the ALSAS-10U with a feed power normalized to 1Watt.

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.



Stuart Nicol



C. Teodorian

## Primary Measurement Standards

Instrument	Serial Number	Cal due date
Power meter Anritsu MA2408A	190025437	Nov.4, 2010
Power Sensor Anritsu MA2481D	103555	Nov 4, 2010
Attenuator HP 8495A (70dB)	1944A10711	Sept. 14, 2010
Network Analyzer Anritsu MT8801C	MB11855	Feb. 8, 2011

## Secondary Measurement Standards

Signal Generator Agilent E4438C -506	MY55182336	June 7, 2011
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## Calibration Results Summary

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

### Mechanical Dimensions

**Length:** 67.1 mm

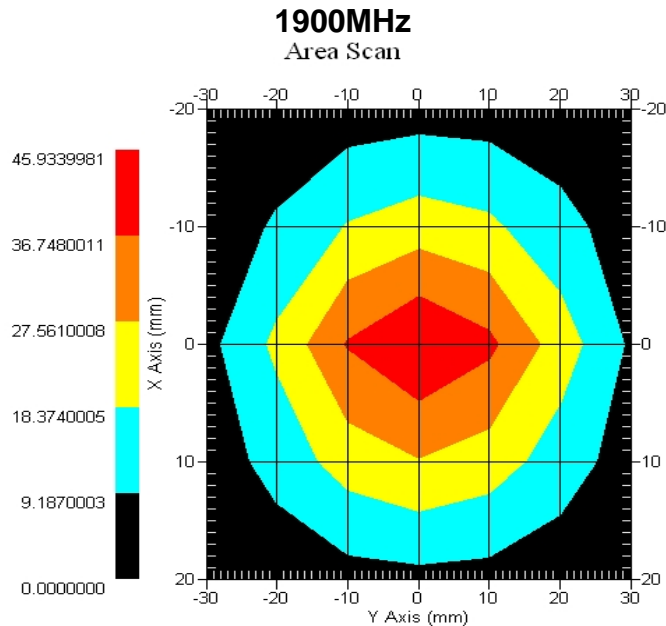
**Height:** 38.9 mm

### Electrical Specification 1900MHz

Tissue Type	Return Loss:	Impedance:	SWR:
Head	-31.943	51.262	1.055U
Body	-25.099	57.750	1.119U

### System Validation Results

Tissue	Frequency	1 Gram	10 Gram	Peak
Head	1900 MHz	39.378	19.668	77.268
Body	1900 MHz	39.654	19.668	77.268



## 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 210-00707. 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-030 130 MHz to 26 GHz E-Field Probe Serial Number 215.

## References

- IEEE Standard 1528 (2003) including Amendment 1  
IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques
- EN 62209-1 (2006)  
Human Exposure to RF Fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures-Part 1: Procedure to measure the Specific Absorption Rate (SAR) for hand-held mobile wireless devices
- IEC 62209-2 Ed. 1.0 (2010-03)  
Human exposure to RF fields from hand-held and body-mounted wireless devices - Human models, instrumentation, and procedures - Part 2: specific absorption rate (SAR) for wireless communication devices (30 MHz - 6 GHz)
- TP-D01-032-E020-V2 E-Field probe calibration procedure
- D22-012-Tissue dielectric tissue calibration procedure
- D28-002-Dipole procedure for validation of SAR system using a dipole
- IEEE 1309 Draft Standard for Calibration of Electromagnetic Field Sensors and Probes, Excluding Antennas, from 9kHz to 40GHz

## Conditions

Dipole 210-00707 was a new dipole taken from stock.

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

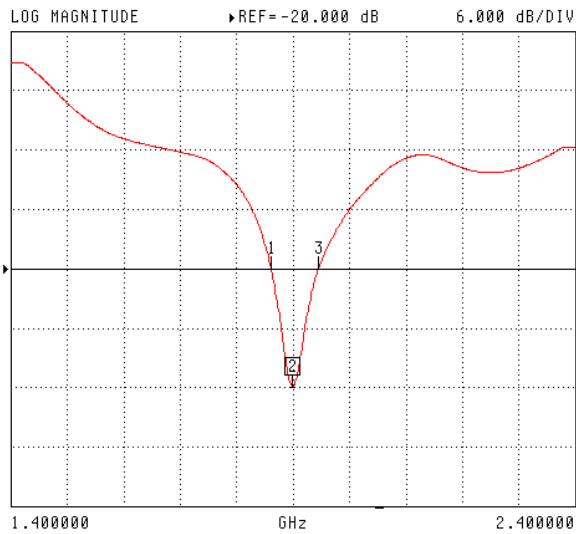
## Electrical Calibration

### Electrical Specification 1900MHz

Tissue Type	Measured Epsilon	Measured Sigma
Head	38.12	1.41
Body	51.52	1.57

#### Head Tissue

S11 FORWARD REFLECTION



CH 1 - S11  
5.0584 mm REF  
0.000 dB OFFSET  
0.00° OFFSET

▶ MARKER 2  
1.900000 GHz  
-31.943 dB

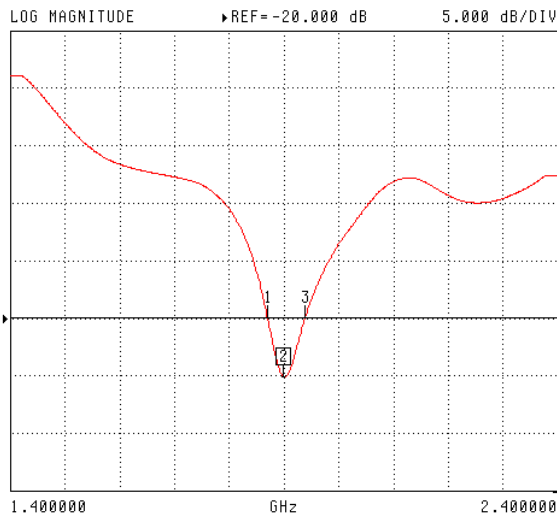
MARKER TO MAX  
MARKER TO MIN

1 1.861600 GHz  
-20.021 dB  
3 1.946000 GHz  
-20.003 dB

MARKER READOUT  
FUNCTIONS

#### Body Tissue

S11 FORWARD REFLECTION



CH 1 - S11  
5.0584 mm REF  
0.000 dB OFFSET  
0.00° OFFSET

▶ MARKER 2  
1.900000 GHz  
-25.099 dB

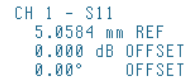
MARKER TO MAX  
MARKER TO MIN

1 1.870600 GHz  
-20.005 dB  
3 1.939500 GHz  
-20.009 dB

MARKER READOUT  
FUNCTIONS

Tissue Type	Measured Epsilon	Measured Sigma
Head	38.12	1.41
Body	51.52	1.57

### S11 FORWARD REFLECTION IMPEDANCE



▶ MARKER 2  
1.900000 GHz  
51.262 Ω  
-1.179 jΩ

MARKER TO MAX  
MARKER TO MIN

- |   |                   |
|---|-------------------|
| 1 | 1.861600 GHz      |
|   | 55.137 $\Omega$   |
|   | 9.602 j $\Omega$  |
| 3 | 1.946000 GHz      |
|   | 41.175 $\Omega$   |
|   | -3.077 j $\Omega$ |

## MARKER READOUT FUNCTIONS

### S11 FORWARD REFLECTION IMPEDANCE



MARKER 2  
1.900000 GHz  
53.750  $\Omega$   
-3.685  $j\Omega$

RKER TO MAX  
RKER TO MIN

- ```

1  1.870600 GHz
    59.559  $\Omega$ 
    5.588  $j\Omega$ 
3  1.939500 GHz
    43.052  $\Omega$ 
    -6.409  $j\Omega$ 

```

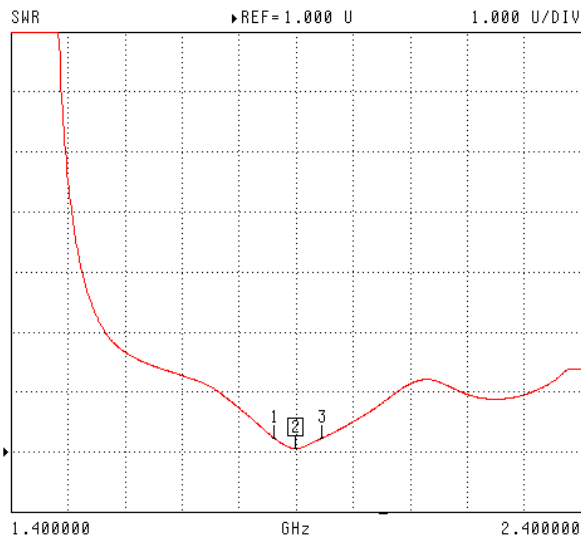
## WORKER READOUT FUNCTIONS

## Electrical Specification 1900MHz Standing Wave Ratio

| Tissue Type | Measured Epsilon | Measured Sigma |
|-------------|------------------|----------------|
| Head        | 38.12            | 1.41           |
| Body        | 51.52            | 1.57           |

### Head Tissue

S11 FORWARD REFLECTION



CH 1 - S11  
5.0584 mm REF  
0.000 dB OFFSET  
0.00° OFFSET

MARKER 2  
1.900000 GHz  
1.055 U

MARKER TO MAX  
MARKER TO MIN

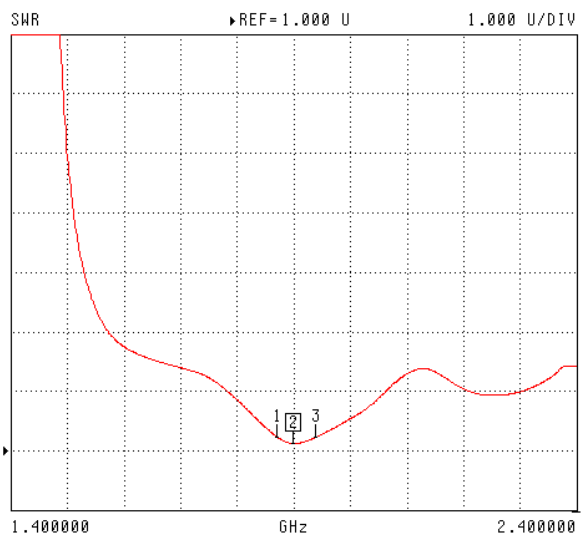
1 1.861600 GHz  
1.234 U

3 1.946000 GHz  
1.227 U

MARKER READOUT  
FUNCTIONS

### Body Tissue

S11 FORWARD REFLECTION



CH 1 - S11  
5.0584 mm REF  
0.000 dB OFFSET  
0.00° OFFSET

MARKER 2  
1.900000 GHz  
1.119 U

MARKER TO MAX  
MARKER TO MIN

1 1.870600 GHz  
1.232 U

3 1.939500 GHz  
1.226 U

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 2011.