

# NCL CALIBRATION LABORATORIES

Calibration File No.: 1233

Client.: APREL

## 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.: 225

Calibration Procedure: D01-032-E020-V2, D22-012-Tissue, D28-002-Dipole  
Project No: Internal

Calibrated: 13<sup>th</sup> January 2011  
Released: 13<sup>th</sup> January 2011

Released By:



**NCL** CALIBRATION LABORATORIES

17 Bentley Ave  
NEPEAN, ONTARIO  
CANADA K2E 6T7

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 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

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Division of APREL Laboratories.

### Conditions

Probe 225 has been recalibrated and was found to be in good working order.

**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.3, 2011
Power Sensor Anritsu MA2481D	103555	Nov 3, 2011
Attenuator HP 8495A (70dB)	1944A10711	Sept. 13, 2011
Network Analyzer Anritsu MT8801C	MB11855	Feb. 8, 2011

### Secondary Measurement Standards

Signal Generator Agilent E4438C -506	MY55182336	June 7, 2011
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### Attestation

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

**NCL Calibration Laboratories**

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Division of APREL Laboratories.

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



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**Dan Brooks**



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**Alain Tran**

## **Calibration Results Summary**

<b>Probe Type:</b>	E-Field Probe E-020
<b>Serial Number:</b>	225
<b>Sensor Offset:</b>	1.56 mm
<b>Sensor Length:</b>	2.5 mm
<b>Tip Enclosure:</b>	Ertalyte*
<b>Tip Diameter:</b>	<2.9 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

## NCL Calibration Laboratories

Division of APREL Laboratories.

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

Frequency	Tissue Type	Measured Epsilon	Measured Sigma	Calibration Uncertainty	Tolerance Uncertainty for 5%*	Conversion Factor
450 H	*FC					
450 B	*FC					
750 H	*FC					
750 B	*FC					
835 H		41.83	0.92	3.5	2.8	7
835 B		57.19	0.94	3.5	2.8	6.6
900 H		41.63	0.96	3.5	2.9	6.4
900 B		53.89	1.02	3.5	2.9	6.3
1450 H	*FC					
1450 B	*FC					
1640 H	*FC					
1640 B	*FC					
1750 H		39.21	1.32	3.5	3.1	6
1750 B		52.01	1.48	3.5	3.1	5.6
1800 H		39.73	1.4	3.5	3.1	5.5
1800 B		52.89	1.51	3.5	3.1	5.2
1900 H		38.12	1.41	3.5	3.1	5.6
1900 B		51.52	1.57	3.5	3.1	5.6
2000 H		38.43	1.37	3.5	3.1	5.8
2000 B		52.29	1.45	3.5	3.1	5.5
2100 H		38.74	1.47	3.5	3.2	5.3
2100B		51.95	1.57	3.5	3.2	5.2
2450 H		37.87	1.82	3.5	3.25	5.2
2450B		50.84	1.92	3.5	3.25	5.0
2600 H		38.87	1.91	3.5	3.8	4.7
2600 B		51.95	2.08	3.5	3.8	4.5
3600 H	*FC					
3600 B	*FC					
5200 H		36.09	4.69	3.5	4.1	3.3
5200 B		49.25	5.27	3.5	4.1	3
5600 H		34.55	5.25	3.5	4.1	3
5600 B		47.73	5.88	3.5	4.1	2.8
5800 H		33.83	5.52	3.5	4.1	3.1
5800 B		47.12	6.17	3.5	4.1	2.9

\*FC, Future Calibration, as required

#### 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 $\Omega$ .

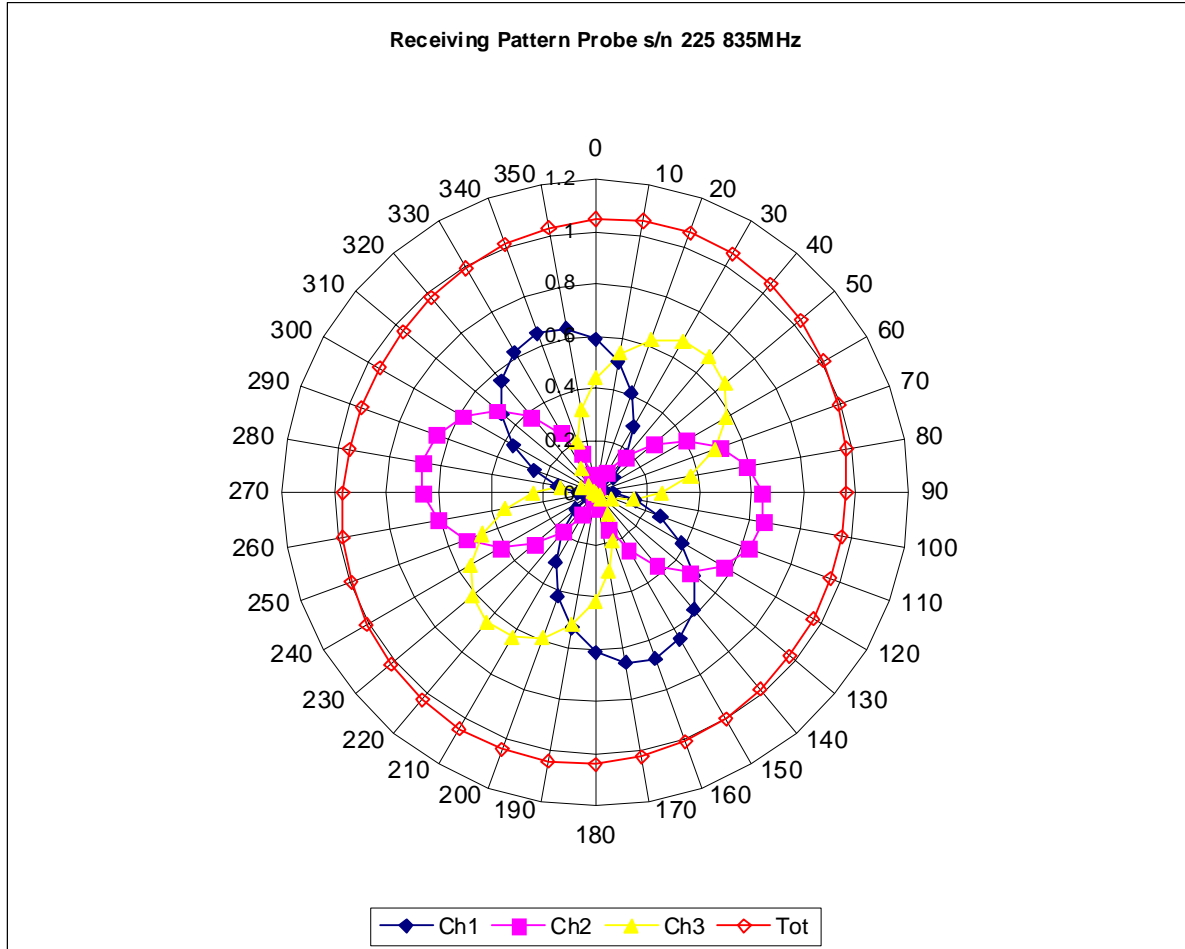
### **Boundary Effect:**

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

### **NOTES:**

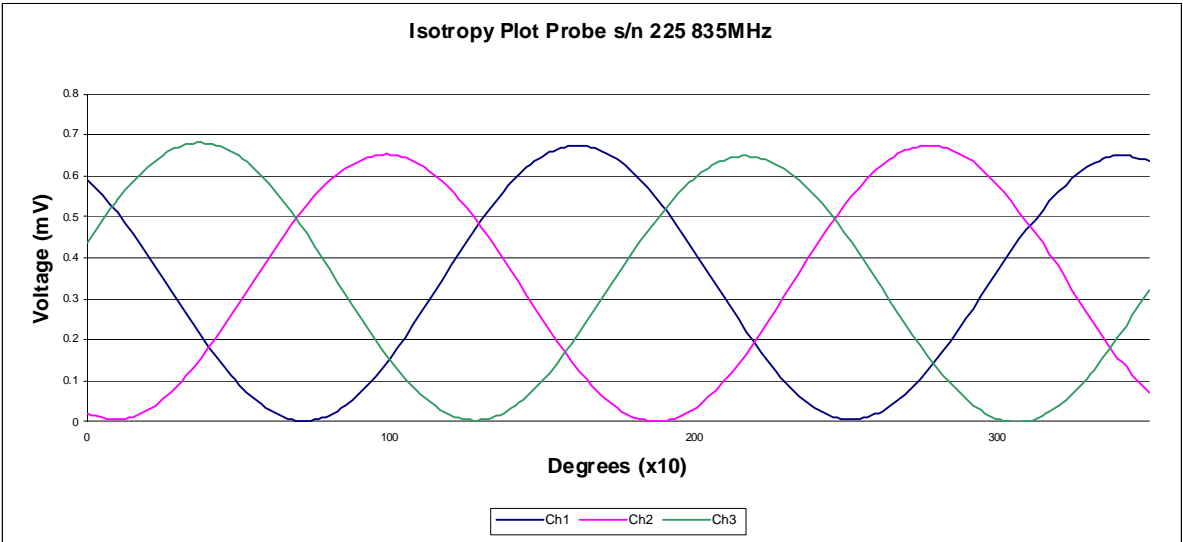
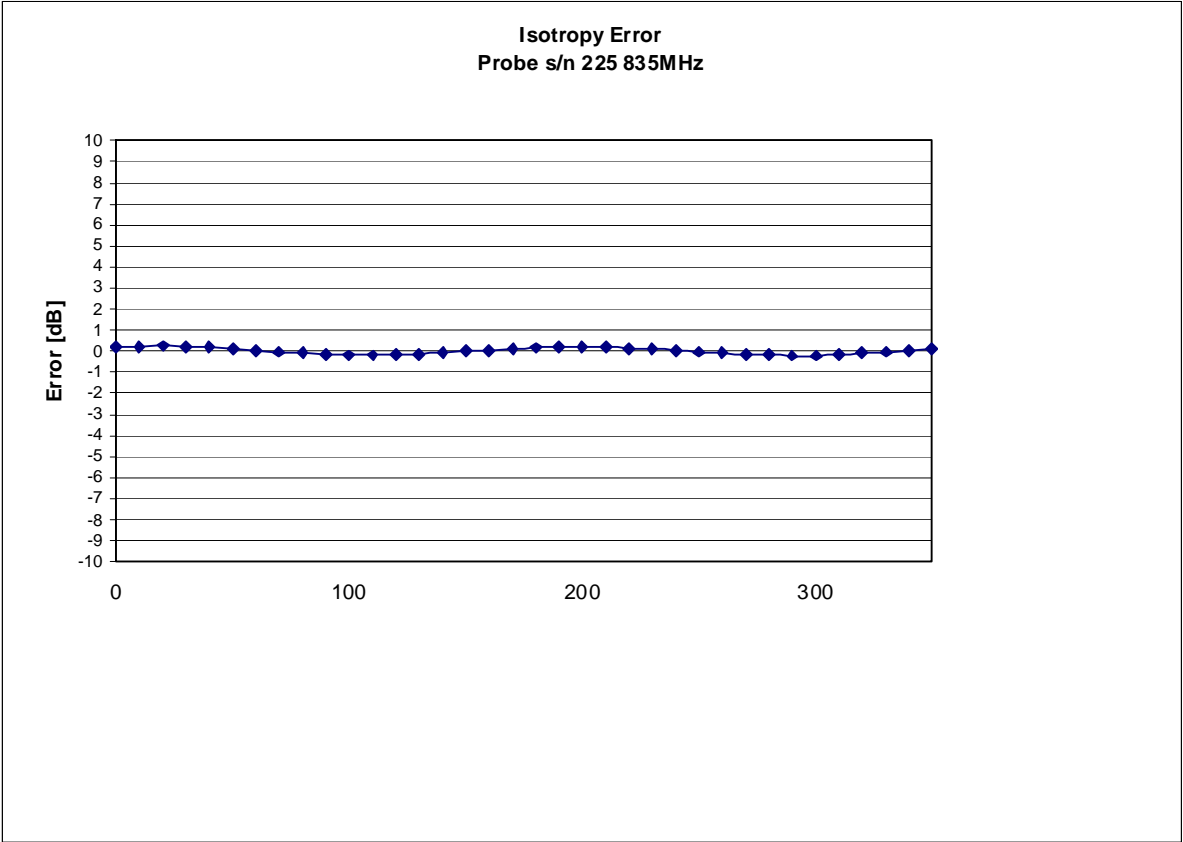
\*The maximum deviation from the centre frequency when comparing the lower to upper range is listed.

## Receiving Pattern Air





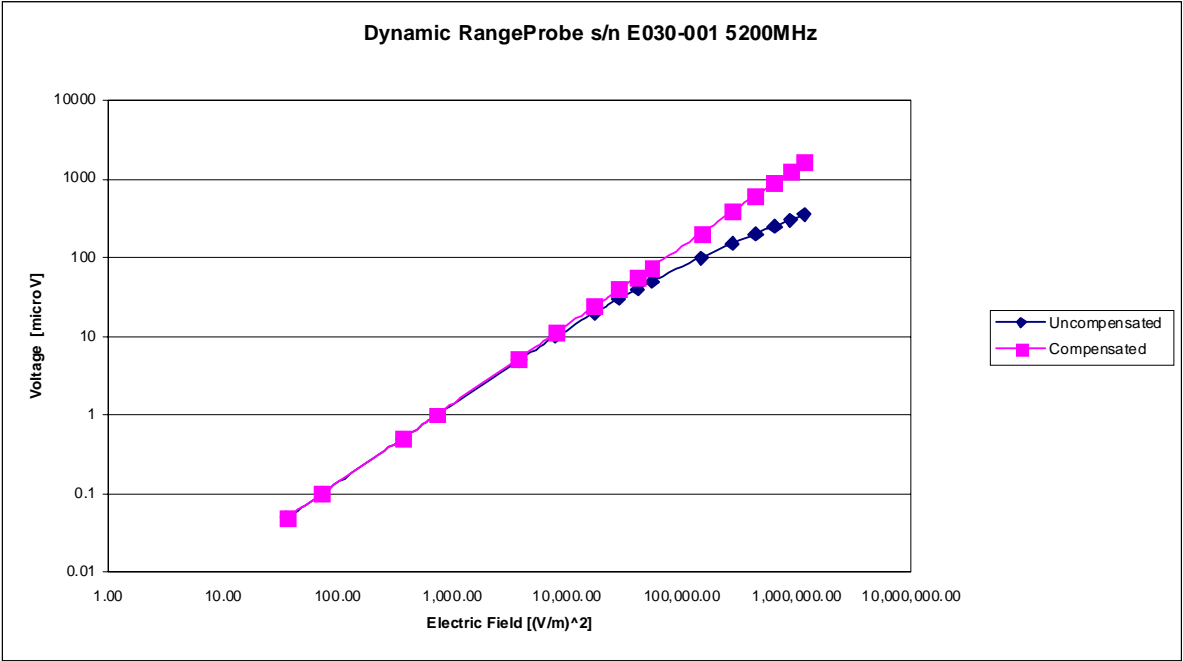
Isotropy Error 5200 MHz (Air)



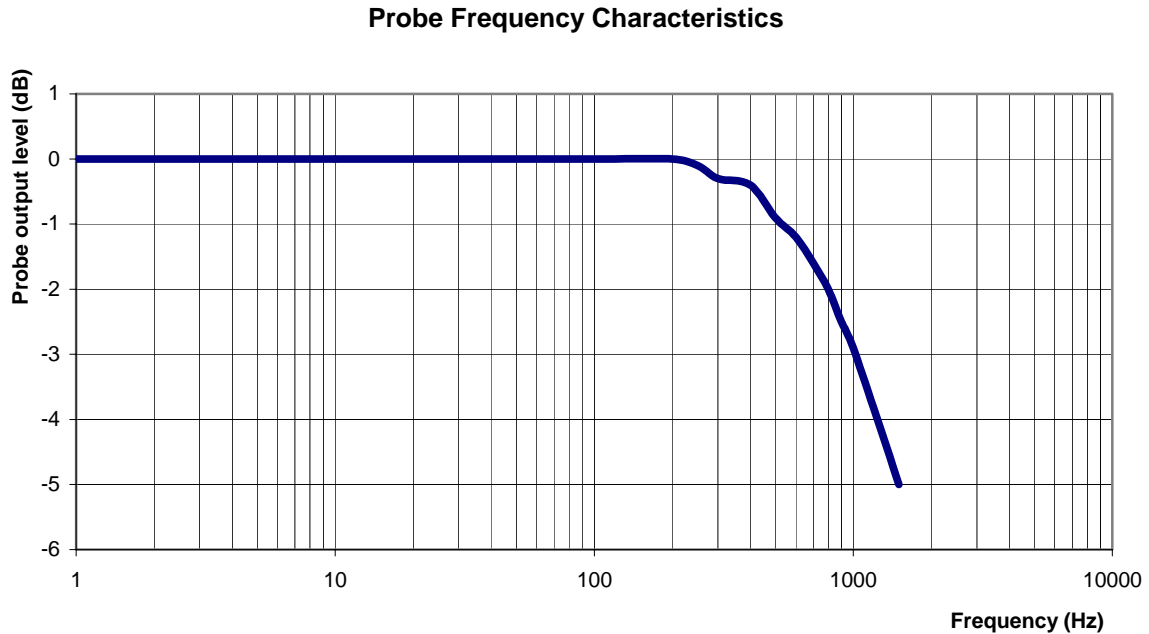
Isotropy Tissue:

0.10 dB

Dynamic Range



## Video Bandwidth



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

## 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 2009.

# NCL CALIBRATION LABORATORIES

Calibration File No: DC-915  
Project Number: APREL-0112

## 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: 180-00554

Customer: APREL

Calibrated: 7<sup>th</sup> July 2010  
Released on: 7<sup>th</sup> July 2010

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

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

**NCL** CALIBRATION LABORATORIES

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TEL: (613) 820-4988  
FAX: (613) 820-4162

## Conditions

Dipole 180-00554 was a re-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.



-----  
**Stuart Nicol**



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**C. Teodorian**

## Primary Measurement Standards

<b>Instrument</b>	<b>Serial Number</b>	<b>Cal due date</b>
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

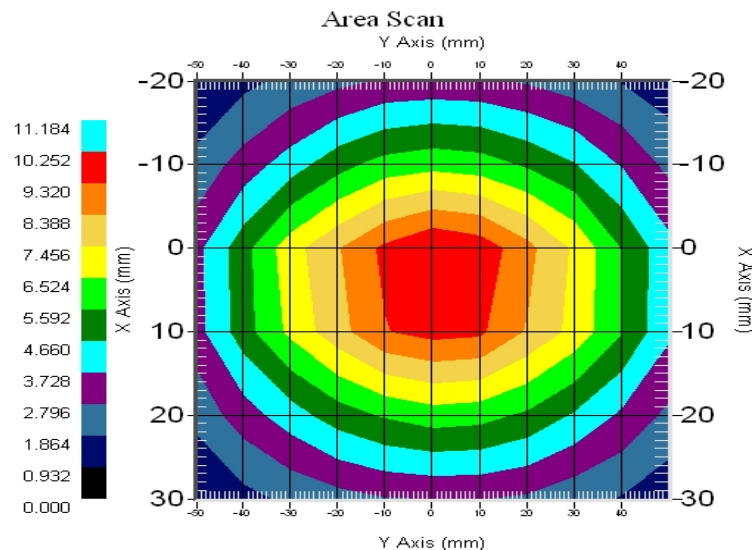
### Electrical Specification 835MHz

Tissue Type	Return Loss:	Impedance:	SWR:
Head	-25.015	51.381	1.124U
Body	-21.254	56.805	1.191U

### 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 180-00554. 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 180-00554 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

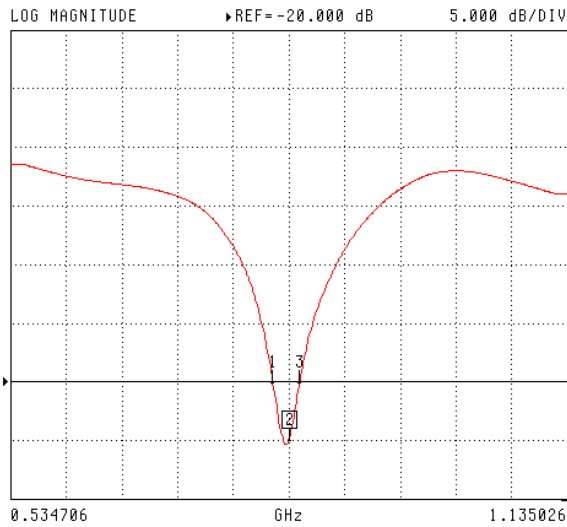
## Electrical Calibration

### Electrical Specification 835MHz

Tissue Type	Measured Epsilon	Measured Sigma
Head	42.38	0.92
Body	57.30	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  
-25.015 dB

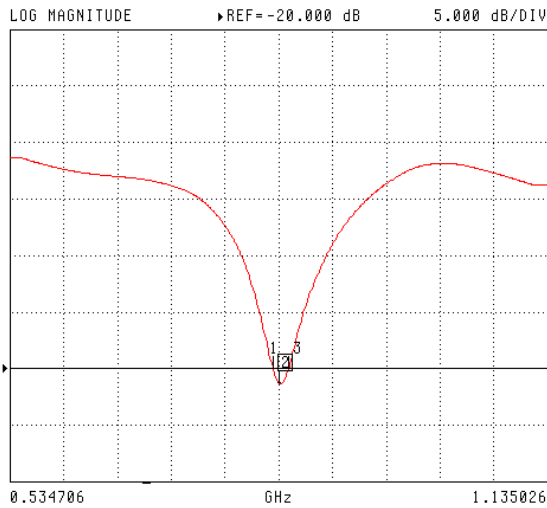
MARKER TO MAX  
MARKER TO MIN

1 0.818000 GHz  
-20.112 dB  
3 0.846648 GHz  
-20.122 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  
-21.254 dB

MARKER TO MAX  
MARKER TO MIN

1 0.828803 GHz  
-20.046 dB  
3 0.846288 GHz  
-20.011 dB

MARKER READOUT  
FUNCTIONS

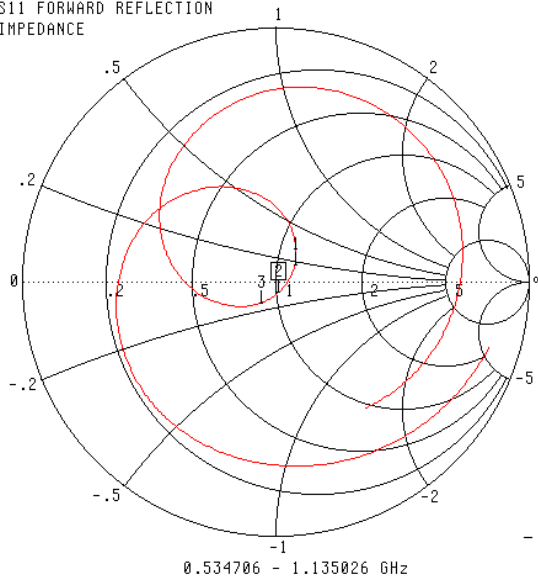
### Electrical Specification 835MHz Impedance



Tissue Type	Measured Epsilon	Measured Sigma
Head	42.38	0.92
Body	57.30	0.95

### Head Tissue

S11 FORWARD REFLECTION  
IMPEDANCE



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

▶ MARKER 2  
0.835000 GHz  
51.381  $\Omega$   
-4.673  $j\Omega$

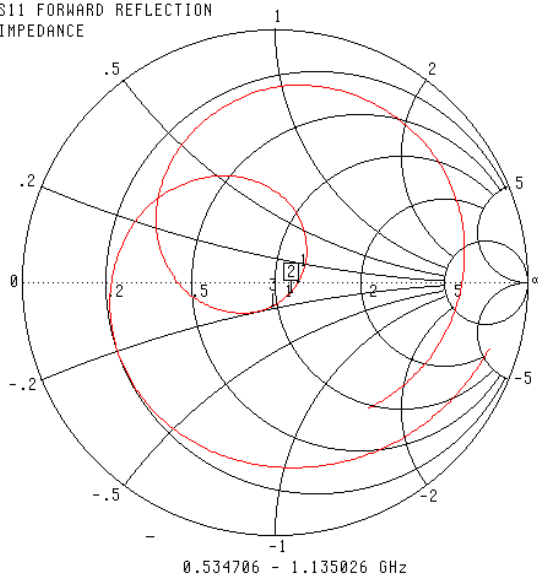
MARKER TO MAX  
MARKER TO MIN

1 0.818000 GHz  
58.164  $\Omega$   
7.657  $j\Omega$   
3 0.846648 GHz  
44.107  $\Omega$   
-7.669  $j\Omega$

MARKER READOUT  
FUNCTIONS

### Body Tissue

S11 FORWARD REFLECTION  
IMPEDANCE



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

▶ MARKER 2  
0.835000 GHz  
56.805  $\Omega$   
-5.050  $j\Omega$

MARKER TO MAX  
MARKER TO MIN

1 0.828003 GHz  
60.568  $\Omega$   
-259.659  $j\Omega$   
3 0.846288 GHz  
48.432  $\Omega$   
-9.493  $j\Omega$

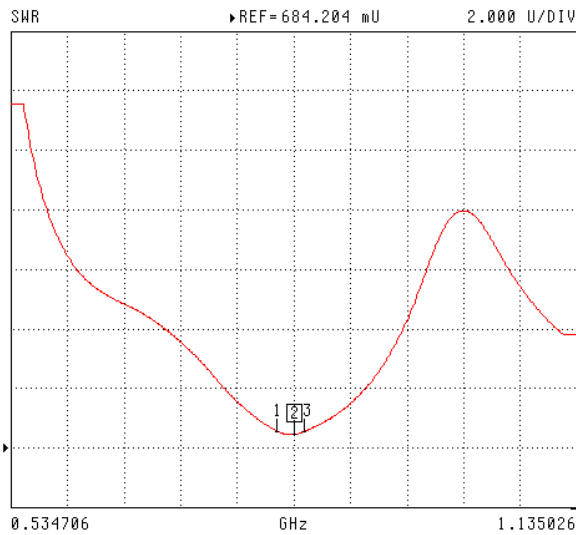
MARKER READOUT  
FUNCTIONS

## Electrical Specification 835MHz Standing Wave Ratio

Tissue Type	Measured Epsilon	Measured Sigma
Head	42.38	0.92
Body	57.30	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  
1.124 U

MARKER TO MAX  
MARKER TO MIN

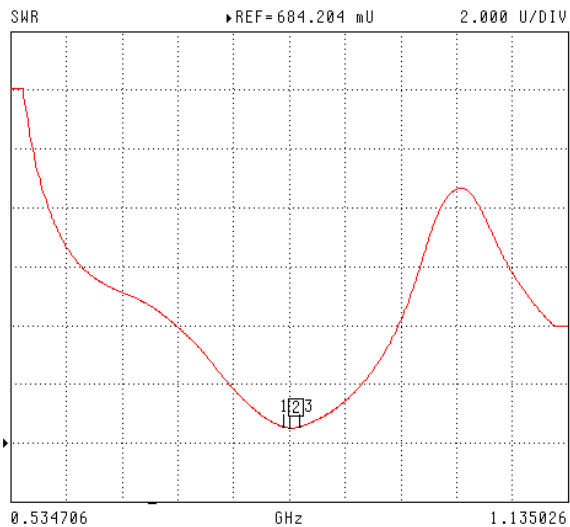
1 0.818000 GHz  
1.237 U

3 0.846648 GHz  
1.232 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  
0.835000 GHz  
1.191 U

MARKER TO MAX  
MARKER TO MIN

1 0.828803 GHz  
1.227 U

3 0.846288 GHz  
1.228 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 2010.

# NCL CALIBRATION LABORATORIES

Calibration File No: DC-916  
Project Number: APREL-0114

## 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  
1900MHz Head & Body

Manufacturer: APREL Laboratories

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

Frequency: 1900MHz

Serial No: 210-00704

Customer: APREL

Calibrated: 12<sup>th</sup> July 2010  
Released on: 12<sup>th</sup> July 2010

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

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

**NCL** CALIBRATION LABORATORIES

17 Bentley Ave

NEPEAN, ONTARIO  
CANADA K2R 1E6

TEL: (613) 820-4988  
FAX: (613) 820-4162

## Conditions

Dipole 210-00704 was a re-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.



-----  
**Stuart Nicol**



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**C. Teodorian**

## Primary Measurement Standards

<b>Instrument</b>	<b>Serial Number</b>	<b>Cal due date</b>
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

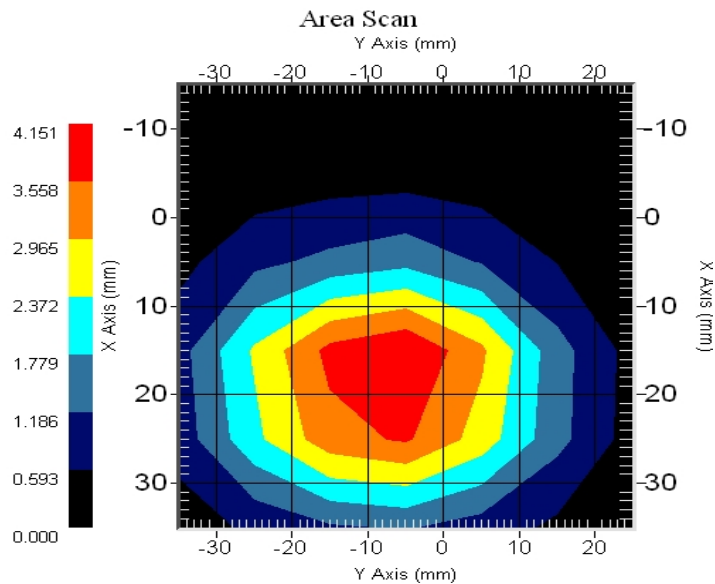
### Electrical Specification 1900MHz

Tissue Type	Return Loss:	Impedance:	SWR:
Head	-36.281	49.633	1.031U
Body	-26.721	51.747	1.097U

### 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

### 1900MHz



## 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 210-00704. 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 210-00704 was a re-calibration.

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

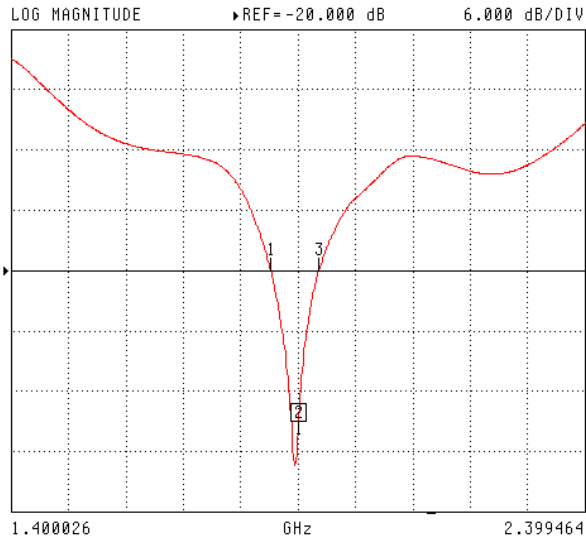
## Electrical Calibration

### Electrical Specification 1900MHz

Tissue Type	Measured Epsilon	Measured Sigma
Head	38.05	1.41
Body	51.11	1.59

#### Head Tissue

S11 FORWARD REFLECTION



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

▶ MARKER 2  
1.900000 GHz  
-36.281 dB

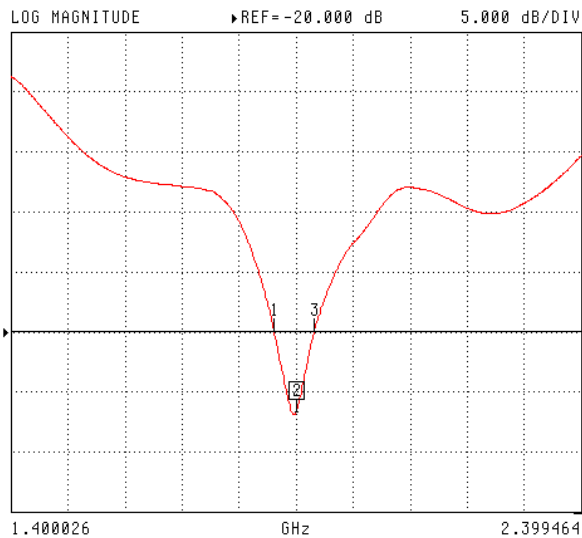
MARKER TO MAX  
MARKER TO MIN

1 1.852719 GHz  
-20.003 dB  
3 1.937020 GHz  
-20.017 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  
-26.721 dB

MARKER TO MAX  
MARKER TO MIN

1 1.861909 GHz  
-20.005 dB  
3 1.932322 GHz  
-20.006 dB

MARKER READOUT  
FUNCTIONS

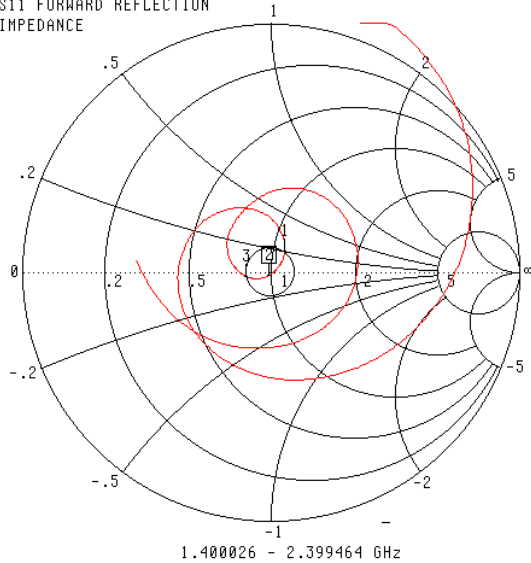


## Electrical Specification 1900MHz Impedance

Tissue Type	Measured Epsilon	Measured Sigma
Head	38.05	1.41
Body	51.11	1.59

### Head Tissue

S11 FORWARD REFLECTION  
IMPEDANCE



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

▶ MARKER 2  
1.900000 GHz  
49.633 Ω  
-1.484 jΩ

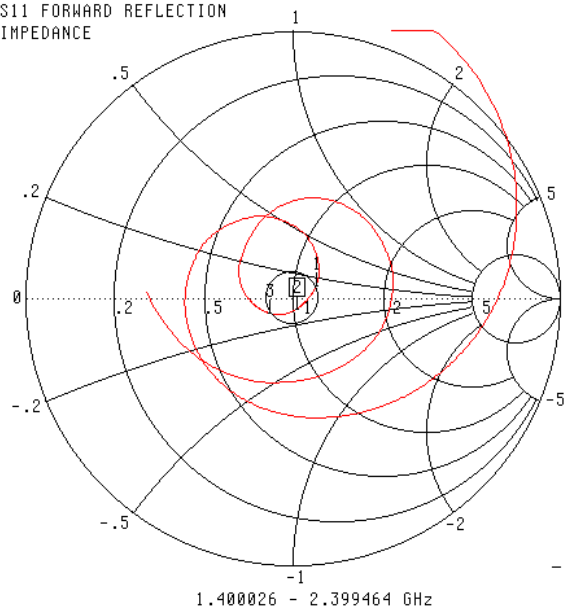
MARKER TO MAX  
MARKER TO MIN

1 1.852719 GHz  
55.483 Ω  
9.052 jΩ  
3 1.937020 GHz  
41.038 Ω  
-1.502 jΩ

MARKER READOUT  
FUNCTIONS

### Body Tissue

S11 FORWARD REFLECTION  
IMPEDANCE



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

▶ MARKER 2  
1.900000 GHz  
51.747 Ω  
-4.358 jΩ

MARKER TO MAX  
MARKER TO MIN

1 1.861909 GHz  
59.716 Ω  
5.110 jΩ  
3 1.932322 GHz  
42.303 Ω  
-5.109 jΩ

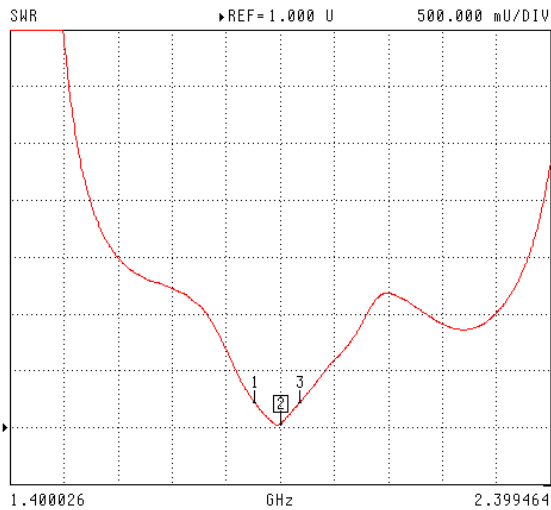
MARKER READOUT  
FUNCTIONS

## Electrical Specification 1900MHz Standing Wave Ratio

Tissue Type	Measured Epsilon	Measured Sigma
Head	38.05	1.41
Body	51.11	1.59

### Head Tissue

S11 FORWARD REFLECTION



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

MARKER 2  
1.900000 GHz  
1.031 U

MARKER TO MAX  
MARKER TO MIN

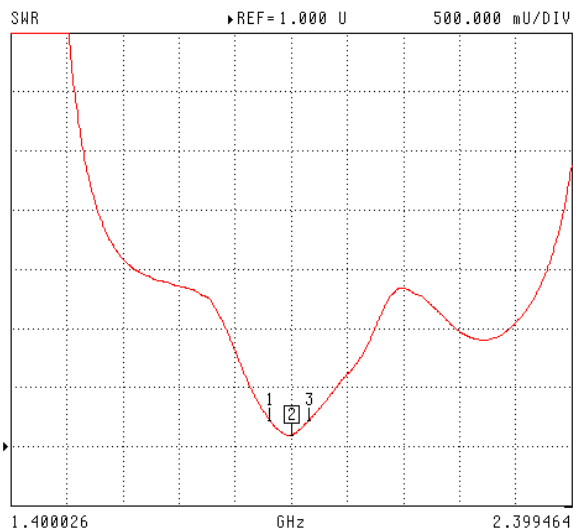
1 1.852719 GHz  
1.222 U

3 1.937020 GHz  
1.222 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  
1.097 U

MARKER TO MAX  
MARKER TO MIN

1 1.861909 GHz  
1.222 U

3 1.932322 GHz  
1.222 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 2010.