

## Appendix D. Calibration Certificate



### COMOSAR E-Field Probe Calibration Report

Ref : ACR.154.4.15.SATU.A

**SHENZHEN SEM.TEST TECHNOLOGY CO., LTD.**

**1/F, BUILDING A, HONGWEI INDUSTRIAL PARK, LIUXIAN  
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**SHENZHEN (518101), CHINA**

**MVG COMOSAR DOSIMETRIC E-FIELD PROBE**

**SERIAL NO.: SN 09/13 EP168**

**Calibrated at MVG US**

**2105 Barrett Park Dr. - Kennesaw, GA 30144**



**06/01/2016**

#### *Summary:*

This document presents the method and results from an accredited COMOSAR Dosimetric E-Field Probe calibration performed in MVG USA using the CALISAR / CALIBAIR test bench, for use with a COMOSAR system only. All calibration results are traceable to national metrology institutions.



**COMOSAR E-FIELD PROBE CALIBRATION REPORT**

Ref: ACR.154.4.15.SATU.A

	<i>Name</i>	<i>Function</i>	<i>Date</i>	<i>Signature</i>
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<i>Distribution :</i>	Shenzhen SEM.Test Technology Co., Ltd.

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Ref: ACR.154.4.15.SATU.A

**1 DEVICE UNDER TEST**

Device Under Test	
Device Type	COMOSAR DOSIMETRIC E FIELD PROBE
Manufacturer	MVG
Model	SSE5
Serial Number	SN 09/13 EP168
Product Condition (new / used)	Used
Frequency Range of Probe	0.7 GHz-3GHz
Resistance of Three Dipoles at Connector	Dipole 1: R1=0.224 MΩ Dipole 2: R2=0.234 MΩ Dipole 3: R3=0.229 MΩ

A yearly calibration interval is recommended.

**2 PRODUCT DESCRIPTION**

**2.1 GENERAL INFORMATION**

MVG's COMOSAR E field Probes are built in accordance to the IEEE 1528, OET 65 Bulletin C and CEI/IEC 62209 standards.



**Figure 1 – MVG COMOSAR Dosimetric E field Dipole**

Probe Length	330 mm
Length of Individual Dipoles	4.5 mm
Maximum external diameter	8 mm
Probe Tip External Diameter	5 mm
Distance between dipoles / probe extremity	2.7 mm

**3 MEASUREMENT METHOD**

The IEEE 1528, OET 65 Bulletin C, CENELEC EN50361 and CEI/IEC 62209 standards provide recommended practices for the probe calibrations, including the performance characteristics of interest and methods by which to assess their affect. All calibrations / measurements performed meet the fore mentioned standards.

**3.1 LINEARITY**

The evaluation of the linearity was done in free space using the waveguide, performing a power sweep to cover the SAR range 0.01W/kg to 100W/kg.



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### **3.2 SENSITIVITY**

The sensitivity factors of the three dipoles were determined using a two step calibration method (air and tissue simulating liquid) using waveguides as outlined in the standards.

### **3.3 LOWER DETECTION LIMIT**

The lower detection limit was assessed using the same measurement set up as used for the linearity measurement. The required lower detection limit is 10 mW/kg.

### **3.4 ISOTROPY**

The axial isotropy was evaluated by exposing the probe to a reference wave from a standard dipole with the dipole mounted under the flat phantom in the test configuration suggested for system validations and checks. The probe was rotated along its main axis from 0 - 360 degrees in 15 degree steps. The hemispherical isotropy is determined by inserting the probe in a thin plastic box filled with tissue-equivalent liquid, with the plastic box illuminated with the fields from a half wave dipole. The dipole is rotated about its axis (0°–180°) in 15° increments. At each step the probe is rotated about its axis (0°–360°).

### **3.5 BOUNDARY EFFECT**

The boundary effect is defined as the deviation between the SAR measured data and the expected exponential decay in the liquid when the probe is oriented normal to the interface. To evaluate this effect, the liquid filled flat phantom is exposed to fields from either a reference dipole or waveguide. With the probe normal to the phantom surface, the peak spatial average SAR is measured and compared to the analytical value at the surface.

## **4 MEASUREMENT UNCERTAINTY**

The guidelines outlined in the IEEE 1528, OET 65 Bulletin C, CENELEC EN50361 and CEI/IEC 62209 standards were followed to generate the measurement uncertainty associated with an E-field probe calibration using the waveguide technique. All uncertainties listed below represent an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of k=2, traceable to the Internationally Accepted Guides to Measurement Uncertainty.

<b>Uncertainty analysis of the probe calibration in waveguide</b>					
<b>ERROR SOURCES</b>	<b>Uncertainty value (%)</b>	<b>Probability Distribution</b>	<b>Divisor</b>	<b>ci</b>	<b>Standard Uncertainty (%)</b>
Incident or forward power	3.00%	Rectangular	$\sqrt{3}$	1	1.732%
Reflected power	3.00%	Rectangular	$\sqrt{3}$	1	1.732%
Liquid conductivity	5.00%	Rectangular	$\sqrt{3}$	1	2.887%
Liquid permittivity	4.00%	Rectangular	$\sqrt{3}$	1	2.309%
Field homogeneity	3.00%	Rectangular	$\sqrt{3}$	1	1.732%
Field probe positioning	5.00%	Rectangular	$\sqrt{3}$	1	2.887%

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Field probe linearity	3.00%	Rectangular	$\sqrt{3}$	1	1.732%
<b>Combined standard uncertainty</b>					5.831%
<b>Expanded uncertainty</b> 95 % confidence level k = 2					12.0%

## 5 CALIBRATION MEASUREMENT RESULTS

Calibration Parameters		
Liquid Temperature	21 °C	
Lab Temperature	21 °C	
Lab Humidity	45 %	

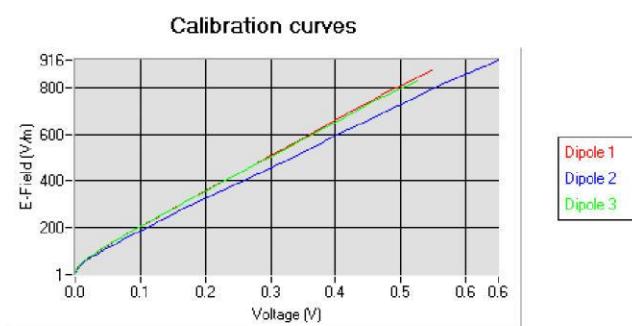
### 5.1 SENSITIVITY IN AIR

Normx dipole 1 ( $\mu\text{V}/(\text{V}/\text{m})^2$ )	Normy dipole 2 ( $\mu\text{V}/(\text{V}/\text{m})^2$ )	Normz dipole 3 ( $\mu\text{V}/(\text{V}/\text{m})^2$ )
4.48	5.48	3.88

DCP dipole 1 (mV)	DCP dipole 2 (mV)	DCP dipole 3 (mV)
105	103	114

Calibration curves  $e_i=f(V)$  ( $i=1,2,3$ ) allow to obtain H-field value using the formula:

$$E = \sqrt{E_1^2 + E_2^2 + E_3^2}$$



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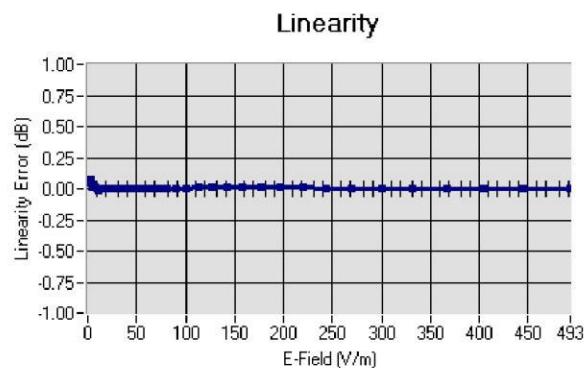
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**5.2 LINEARITY**



Linearity: +/-1.62% (+/-0.07dB)

**5.3 SENSITIVITY IN LIQUID**

Liquid	Frequency [MHz/+100MHz]	Permittivity	Epsilon(\$/m)	ConvF
HL750	750	41.90	0.89	6.99
BL750	750	55.50	0.96	7.28
HL850	850	42.59	0.90	6.93
BL850	850	53.19	0.97	7.13
HL900	900	42.05	0.98	6.18
BL900	900	56.41	1.08	6.41
HL1800	1800	41.82	1.38	5.84
BL1800	1800	53.00	1.52	6.06
HL1900	1900	40.38	1.41	6.35
BL1900	1900	53.93	1.55	6.55
HL2000	2000	40.12	1.43	5.76
BL2000	2000	53.65	1.54	5.88
HL2450	2450	38.34	1.80	5.64
BL2450	2450	52.70	1.94	5.80
HL2600	2600	38.16	1.93	5.37
BL2600	2600	51.55	2.21	5.58

LOWER DETECTION LIMIT: 7mW/kg

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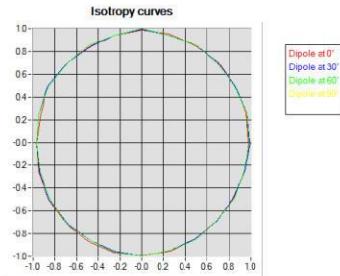
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Ref: ACR.154.4.15.SATU.A

**5.4 ISOTROPY**

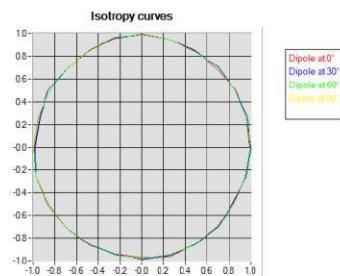
**HL900 MHz**

- Axial isotropy: 0.04 dB
- Hemispherical isotropy: 0.05 dB



**HL1800 MHz**

- Axial isotropy: 0.04 dB
- Hemispherical isotropy: 0.06 dB





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**6 LIST OF EQUIPMENT**

Equipment Summary Sheet				
Equipment Description	Manufacturer / Model	Identification No.	Current Calibration Date	Next Calibration Date
Flat Phantom	MVG	SN-20/09-SAM71	Validated. No cal required.	Validated. No cal required.
COMOSAR Test Bench	Version 3	NA	Validated. No cal required.	Validated. No cal required.
Network Analyzer	Rhode & Schwarz ZVA	SN100132	02/2016	02/2019
Reference Probe	MVG	EP 94 SN 37/08	10/2015	10/2016
Multimeter	Keithley 2000	1188656	12/2013	12/2016
Signal Generator	Agilent E4438C	MY49070581	12/2013	12/2016
Amplifier	Aethercomm	SN 046	Characterized prior to test. No cal required.	Characterized prior to test. No cal required.
Power Meter	HP E4418A	US38261498	12/2013	12/2016
Power Sensor	HP ECP-E26A	US37181460	12/2013	12/2016
Directional Coupler	Narda 4216-20	01386	Characterized prior to test. No cal required.	Characterized prior to test. No cal required.
Waveguide	Mega Industries	069Y7-158-13-712	Validated. No cal required.	Validated. No cal required.
Waveguide Transition	Mega Industries	069Y7-158-13-701	Validated. No cal required.	Validated. No cal required.
Waveguide Termination	Mega Industries	069Y7-158-13-701	Validated. No cal required.	Validated. No cal required.
Temperature / Humidity Sensor	Control Company	11-661-9	8/2015	8/2018



## SAR Reference Dipole Calibration Report

Ref : ACR.75.1.15.SATU.A

**Shenzhen SEM.Test Technology Co., Ltd.**  
1/F, Building A, Hongwei Industrial Park, Liuxian 2<sup>nd</sup> Road  
BAO'AN DISTRICT  
SHENZHEN, P.R.C. (518101)  
**MVG COMOSAR REFERENCE DIPOLE**  
**FREQUENCY: 835 MHZ**  
**SERIAL NO.: SN 47/12 DIP 0G835-204**

Calibrated at MVG US  
2105 Barrett Park Dr. - Kennesaw, GA 30144



03/20/2016

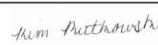
### Summary:

This document presents the method and results from an accredited SAR reference dipole calibration performed in MVG USA using the COMOSAR test bench. All calibration results are traceable to national metrology institutions.



SAR REFERENCE DIPOLE CALIBRATION REPORT

Ref: ACR.75.1.15.SATU.A

	Name	Function	Date	Signature
Prepared by :	Jérôme LUC	Product Manager	3/20/2016	
Checked by :	Jérôme LUC	Product Manager	3/20/2016	
Approved by :	Kim RUTKOWSKI	Quality Manager	3/20/2016	

	Customer Name
Distribution :	Shenzhen SEM Test Technology Co., Ltd.

Issue	Date	Modifications
A	3/20/2016	Initial release

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**SAR REFERENCE DIPOLE CALIBRATION REPORT**

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**1 INTRODUCTION**

This document contains a summary of the requirements set forth by the IEEE 1528, FCC KDBs and CEI/IEC 62209 standards for reference dipoles used for SAR measurement system validations and the measurements that were performed to verify that the product complies with the fore mentioned standards.

**2 DEVICE UNDER TEST**

<b>Device Under Test</b>	
Device Type	COMOSAR 835 MHz REFERENCE DIPOLE
Manufacturer	MVG
Model	SID835
Serial Number	SN 47/12 DIP 0G835-204
Product Condition (new / used)	Used

A yearly calibration interval is recommended.

**3 PRODUCT DESCRIPTION**

**3.1 GENERAL INFORMATION**

MVG's COMOSAR Validation Dipoles are built in accordance to the IEEE 1528, FCC KDBs and CEI/IEC 62209 standards. The product is designed for use with the COMOSAR test bench only.



**Figure 1 – MVG COMOSAR Validation Dipole**



SAR REFERENCE DIPOLE CALIBRATION REPORT

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#### 4 MEASUREMENT METHOD

The IEEE 1528, FCC KDBs and CEI/IEC 62209 standards provide requirements for reference dipoles used for system validation measurements. The following measurements were performed to verify that the product complies with the fore mentioned standards.

##### 4.1 RETURN LOSS REQUIREMENTS

The dipole used for SAR system validation measurements and checks must have a return loss of -20 dB or better. The return loss measurement shall be performed against a liquid filled flat phantom, with the phantom constructed as outlined in the fore mentioned standards.

##### 4.2 MECHANICAL REQUIREMENTS

The IEEE Std. 1528 and CEI/IEC 62209 standards specify the mechanical components and dimensions of the validation dipoles, with the dimensions frequency and phantom shell thickness dependent. The COMOSAR test bench employs a 2 mm phantom shell thickness therefore the dipoles sold for use with the COMOSAR test bench comply with the requirements set forth for a 2 mm phantom shell thickness.

#### 5 MEASUREMENT UNCERTAINTY

All uncertainties listed below represent an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of k=2, traceable to the Internationally Accepted Guides to Measurement Uncertainty.

##### 5.1 RETURN LOSS

The following uncertainties apply to the return loss measurement:

Frequency band	Expanded Uncertainty on Return Loss
400-6000MHz	0.1 dB

##### 5.2 DIMENSION MEASUREMENT

The following uncertainties apply to the dimension measurements:

Length (mm)	Expanded Uncertainty on Length
3 - 300	0.05 mm

##### 5.3 VALIDATION MEASUREMENT

The guidelines outlined in the IEEE 1528, FCC KDBs, CENELEC EN50361 and CEI/IEC 62209 standards were followed to generate the measurement uncertainty for validation measurements.

Scan Volume	Expanded Uncertainty
1 g	20.3 %

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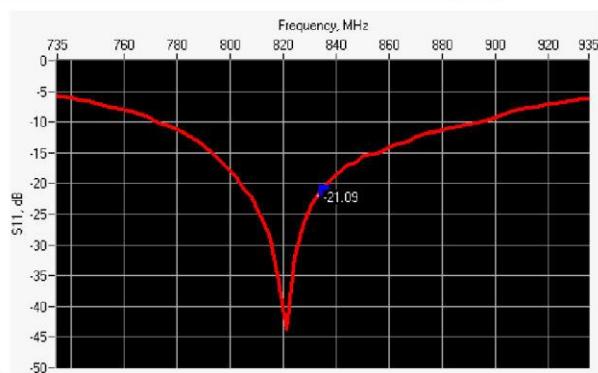
SAR REFERENCE DIPOLE CALIBRATION REPORT

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10 g	20.1 %
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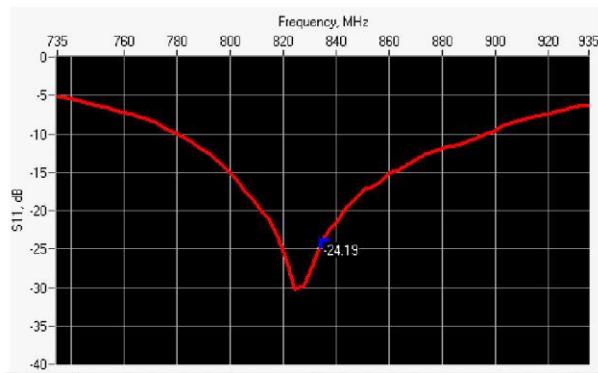
## 6 CALIBRATION MEASUREMENT RESULTS

### 6.1 RETURN LOSS AND IMPEDANCE IN HEAD LIQUID



Frequency (MHz)	Return Loss (dB)	Requirement (dB)	Impedance
835	-21.09	-20	$59.5 \Omega - 1.2 j\Omega$

### 6.2 RETURN LOSS AND IMPEDANCE IN BODY LIQUID



Frequency (MHz)	Return Loss (dB)	Requirement (dB)	Impedance
835	-24.19	-20	$55.8 \Omega + 3.0 j\Omega$

### 6.3 MECHANICAL DIMENSIONS

Frequency MHz	L mm		h mm		d mm	
	required	measured	required	measured	required	measured
300	$420.0 \pm 1\%$ .		$250.0 \pm 1\%$ .		$6.35 \pm 1\%$ .	

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450	290.0 ±1 %.		166.7 ±1 %.		6.35 ±1 %.	
750	176.0 ±1 %.		100.0 ±1 %.		6.35 ±1 %.	
835	161.0 ±1 %.	PASS	89.8 ±1 %.	PASS	3.6 ±1 %.	PASS
900	149.0 ±1 %.		83.3 ±1 %.		3.6 ±1 %.	
1450	89.1 ±1 %.		51.7 ±1 %.		3.6 ±1 %.	
1500	80.5 ±1 %.		50.0 ±1 %.		3.6 ±1 %.	
1640	79.0 ±1 %.		45.7 ±1 %.		3.6 ±1 %.	
1750	75.2 ±1 %.		42.9 ±1 %.		3.6 ±1 %.	
1800	72.0 ±1 %.		41.7 ±1 %.		3.6 ±1 %.	
1900	68.0 ±1 %.		39.5 ±1 %.		3.6 ±1 %.	
1950	66.3 ±1 %.		38.5 ±1 %.		3.6 ±1 %.	
2000	64.5 ±1 %.		37.5 ±1 %.		3.6 ±1 %.	
2100	61.0 ±1 %.		35.7 ±1 %.		3.6 ±1 %.	
2300	55.5 ±1 %.		32.6 ±1 %.		3.6 ±1 %.	
2450	51.5 ±1 %.		30.4 ±1 %.		3.6 ±1 %.	
2600	48.5 ±1 %.		28.8 ±1 %.		3.6 ±1 %.	
3000	41.5 ±1 %.		25.0 ±1 %.		3.6 ±1 %.	
3500	37.0 ±1 %.		26.4 ±1 %.		3.6 ±1 %.	
3700	34.7 ±1 %.		26.4 ±1 %.		3.6 ±1 %.	

## 7 VALIDATION MEASUREMENT

The IEEE Std. 1528, FCC KDBs and CEI/IEC 62209 standards state that the system validation measurements must be performed using a reference dipole meeting the fore mentioned return loss and mechanical dimension requirements. The validation measurement must be performed against a liquid filled flat phantom, with the phantom constructed as outlined in the fore mentioned standards. Per the standards, the dipole shall be positioned below the bottom of the phantom, with the dipole length centered and parallel to the longest dimension of the flat phantom, with the top surface of the dipole at the described distance from the bottom surface of the phantom.

### 7.1 HEAD LIQUID MEASUREMENT

Frequency MHz	Relative permittivity ( $\epsilon_r'$ )		Conductivity ( $\sigma$ ) S/m	
	required	measured	required	measured
300	45.3 ±5 %		0.87 ±5 %	
450	43.5 ±5 %		0.87 ±5 %	
750	41.9 ±5 %		0.89 ±5 %	
835	41.5 ±5 %	PASS	0.90 ±5 %	PASS
900	41.5 ±5 %		0.97 ±5 %	
1450	40.5 ±5 %		1.20 ±5 %	
1500	40.4 ±5 %		1.23 ±5 %	
1640	40.2 ±5 %		1.31 ±5 %	
1750	40.1 ±5 %		1.37 ±5 %	

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1800	40.0 ± 5 %		1.40 ± 5 %	
1900	40.0 ± 5 %		1.40 ± 5 %	
1950	40.0 ± 5 %		1.40 ± 5 %	
2000	40.0 ± 5 %		1.40 ± 5 %	
2100	39.8 ± 5 %		1.49 ± 5 %	
2300	39.5 ± 5 %		1.67 ± 5 %	
2450	39.2 ± 5 %		1.80 ± 5 %	
2600	39.0 ± 5 %		1.96 ± 5 %	
3000	38.5 ± 5 %		2.40 ± 5 %	
3500	37.9 ± 5 %		2.91 ± 5 %	

**7.2 SAR MEASUREMENT RESULT WITH HEAD LIQUID**

The IEEE Std. 1528 and CEI/IEC 62209 standards state that the system validation measurements should produce the SAR values shown below (for phantom thickness of 2 mm), within the uncertainty for the system validation. All SAR values are normalized to 1 W forward power. In bracket, the measured SAR is given with the used input power.

Software	OPENSAR V4
Phantom	SN 20/09 SAM71
Probe	SN 18/11 EPG122
Liquid	Head Liquid Values: $\epsilon_s'$ : 42.1 sigma : 0.92
Distance between dipole center and liquid	15.0 mm
Area scan resolution	$dx=8\text{mm}/dy=8\text{mm}$
Zoon Scan Resolution	$dx=8\text{mm}/dy=8\text{mm}/dz=5\text{mm}$
Frequency	835 MHz
Input power	20 dBm
Liquid Temperature	21 °C
Lab Temperature	21 °C
Lab Humidity	45 %

Frequency MHz	1 g SAR (W/kg/W)		10 g SAR (W/kg/W)	
	required	measured	required	measured
300	2.85		1.94	
450	4.58		3.06	
750	8.49		5.55	
835	9.56	9.67 (0.98)	6.22	6.29 (0.65)
900	10.9		6.99	
1450	29		16	
1500	30.5		16.8	
1640	34.2		18.4	
1750	36.4		19.3	
1800	38.4		20.1	

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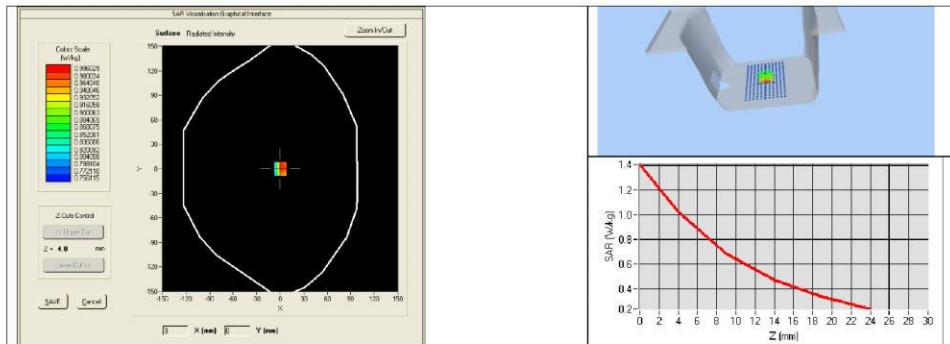
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1900	39.7		20.5	
1950	40.5		20.9	
2000	41.1		21.1	
2100	43.6		21.9	
2300	48.7		23.3	
2450	52.4		24	
2600	55.3		24.6	
3000	63.8		25.7	
3500	67.1		25	



### 7.3 BODY LIQUID MEASUREMENT

Frequency MHz	Relative permittivity ( $\epsilon_r'$ )		Conductivity ( $\sigma$ ) S/m	
	required	measured	required	measured
150	61.9 ±5 %		0.80 ±5 %	
300	58.2 ±5 %		0.92 ±5 %	
450	56.7 ±5 %		0.94 ±5 %	
750	55.5 ±5 %		0.96 ±5 %	
835	55.2 ±5 %	PASS	0.97 ±5 %	PASS
900	55.0 ±5 %		1.05 ±5 %	
915	55.0 ±5 %		1.06 ±5 %	
1450	54.0 ±5 %		1.30 ±5 %	
1610	53.8 ±5 %		1.40 ±5 %	
1800	53.3 ±5 %		1.52 ±5 %	
1900	53.3 ±5 %		1.52 ±5 %	
2000	53.3 ±5 %		1.52 ±5 %	
2100	53.2 ±5 %		1.62 ±5 %	
2450	52.7 ±5 %		1.95 ±5 %	

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**SAR REFERENCE DIPOLE CALIBRATION REPORT**

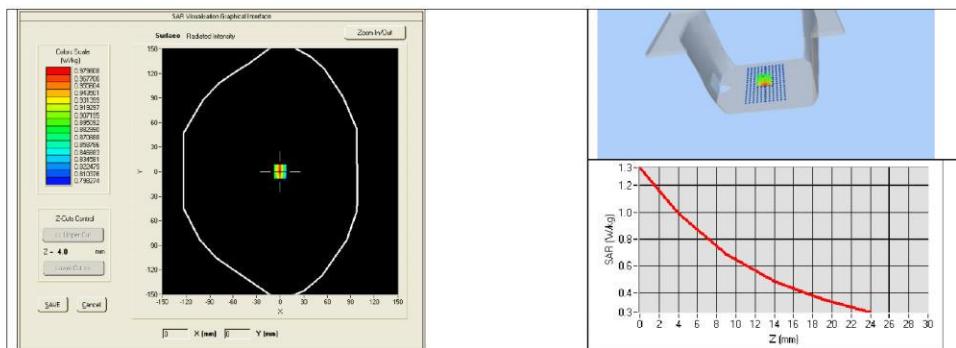
Ref: ACR.75.1.15.SATU.A

2600	52.5 ± 5 %		2.16 ± 5 %	
3000	52.0 ± 5 %		2.73 ± 5 %	
3500	51.3 ± 5 %		3.31 ± 5 %	
5200	49.0 ± 10 %		5.30 ± 10 %	
5300	48.9 ± 10 %		5.42 ± 10 %	
5400	48.7 ± 10 %		5.53 ± 10 %	
5500	48.6 ± 10 %		5.65 ± 10 %	
5600	48.5 ± 10 %		5.77 ± 10 %	
5800	48.2 ± 10 %		6.00 ± 10 %	

**7.4 SAR MEASUREMENT RESULT WITH BODY LIQUID**

Software	OPENSAR V4
Phantom	SN 20/09 SAM71
Probe	SN 18/11 EPG122
Liquid	Body Liquid Values: $\epsilon_s'$ : 53.8 sigma : 0.98
Distance between dipole center and liquid	15.0 mm
Area scan resolution	$dx=8\text{mm}/dy=8\text{mm}$
Zoon Scan Resolution	$dx=8\text{mm}/dy=8\text{m}/dz=5\text{mm}$
Frequency	835 MHz
Input power	20 dBm
Liquid Temperature	21 °C
Lab Temperature	21 °C
Lab Humidity	45 %

Frequency MHz	1 g SAR (W/kg/W)	10 g SAR (W/kg/W)
	measured	measured
835	9.38 (0.99)	6.23 (0.66)



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SAR REFERENCE DIPOLE CALIBRATION REPORT

Ref: ACR.75.1.15.SATU.A

**8 LIST OF EQUIPMENT**

Equipment Summary Sheet				
Equipment Description	Manufacturer / Model	Identification No.	Current Calibration Date	Next Calibration Date
SAM Phantom	MVG	SN-20/09-SAM71	Validated. No cal required.	Validated. No cal required.
COMOSAR Test Bench	Version 3	NA	Validated. No cal required.	Validated. No cal required.
Network Analyzer	Rhode & Schwarz ZVA	SN100132	02/2016	02/2019
Calipers	Carrera	CALIPER-01	12/2013	12/2016
Reference Probe	MVG	EPG122 SN 18/11	10/2015	10/2016
Multimeter	Keithley 2000	1188656	12/2013	12/2016
Signal Generator	Agilent E4438C	MY49070581	12/2013	12/2016
Amplifier	Aethercomm	SN 046	Characterized prior to test. No cal required.	Characterized prior to test. No cal required.
Power Meter	HP E4418A	US38261498	12/2013	12/2016
Power Sensor	HP ECP-E26A	US37181460	12/2013	12/2016
Directional Coupler	Narda 4216-20	01386	Characterized prior to test. No cal required.	Characterized prior to test. No cal required.
Temperature and Humidity Sensor	Control Company	11-661-9	8/2015	8/2018

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## SAR Reference Dipole Calibration Report

Ref : ACR.75.3.15.SATU.A

**Shenzhen SEM.Test Technology Co., Ltd.**  
1/F, Building A, Hongwei Industrial Park, Liuxian 2<sup>nd</sup> Road  
BAO'AN DISTRICT  
SHENZHEN, P.R.C. (518101)  
**MVG COMOSAR REFERENCE DIPOLE**  
**FREQUENCY: 1800 MHZ**  
**SERIAL NO.: SN 47/12 DIP 1G800-206**

Calibrated at MVG US  
2105 Barrett Park Dr. - Kennesaw, GA 30144



03/20/2016

### Summary:

This document presents the method and results from an accredited SAR reference dipole calibration performed in MVG USA using the COMOSAR test bench. All calibration results are traceable to national metrology institutions.