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## 1 INTRODUCTION

This document contains a summary of the requirements set forth by the IEEE 1528 and CEI/IEC 62209 standards for reference waveguides 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

Device Under Test	
Device Type	COMOSAR 5000-6000 MHz REFERENCE WAVEGUIDE
Manufacturer	MVG
Model	SWG5500
Serial Number	SN 15/15 WGA39
Product Condition (new / used)	Used

## 3 PRODUCT DESCRIPTION

### 3.1 GENERAL INFORMATION

MVG's COMOSAR Validation Waveguides are built in accordance to the IEEE 1528 and CEI/IEC 62209 standards.

## 4 MEASUREMENT METHOD

The IEEE 1528 and CEI/IEC 62209 standards provide requirements for reference waveguides 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 waveguide used for SAR system validation measurements and checks must have a return loss of -8 dB or better. The return loss measurement shall be performed with matching layer placed in the open end of the waveguide, with the waveguide and matching layer in direct contact with the phantom shell as outlined in the fore mentioned standards. A direct method is used with a network analyser and its calibration kit, both with a valid ISO17025 calibration.

### 4.2 MECHANICAL REQUIREMENTS

The IEEE 1528 and CEI/IEC 62209 standards specify the mechanical dimensions of the validation waveguide, the specified dimensions are as shown in Section 6.2. Figure 1 shows how the dimensions relate to the physical construction of the waveguide. A direct method is used with a ISO17025 calibrated caliper.



## 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	0.08 LIN

### 5.2 DIMENSION MEASUREMENT

The following uncertainties apply to the dimension measurements:

Length (mm)	Expanded Uncertainty on Length
0 - 300	0.20 mm

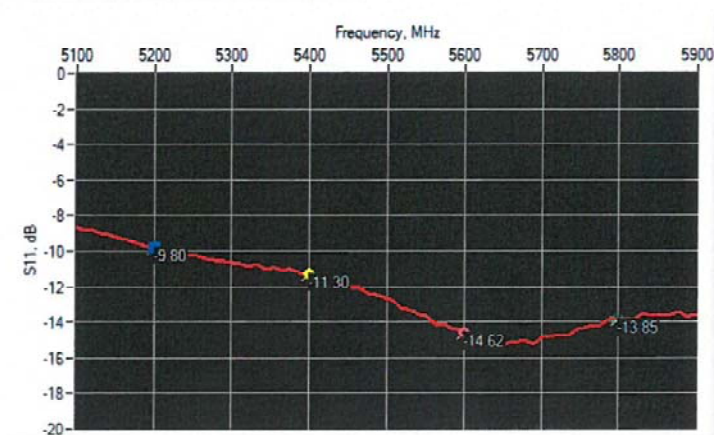
### 5.3 VALIDATION MEASUREMENT

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

Scan Volume	Expanded Uncertainty
1 g	19 % (SAR)
10 g	19 % (SAR)

## 6 CALIBRATION MEASUREMENT RESULTS

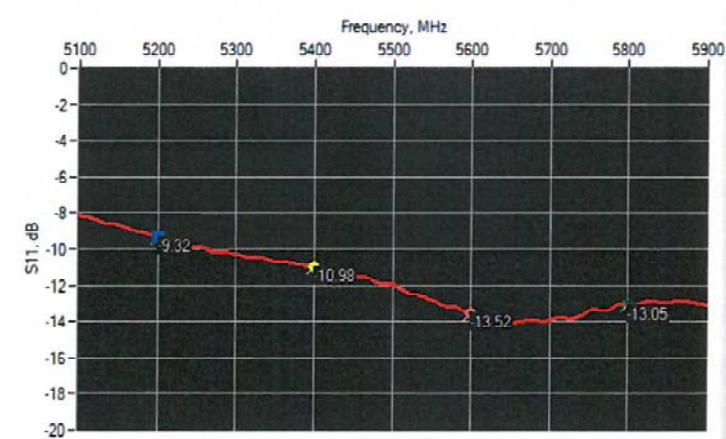
### 6.1 RETURN LOSS IN HEAD LIQUID





Frequency (MHz)	Return Loss (dB)	Requirement (dB)	Impedance
5200	-9.80	-8	$22.19 \Omega + 10.27 j\Omega$
5400	-11.30	-8	$75.26 \Omega + 2.27 j\Omega$
5600	-14.62	-8	$34.93 \Omega - 10.02 j\Omega$
5800	-13.85	-8	$55.11 \Omega + 19.16 j\Omega$

## 6.2 RETURN LOSS IN BODY LIQUID

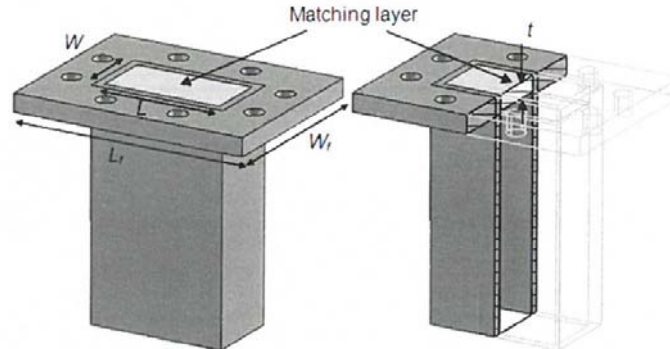


Frequency (MHz)	Return Loss (dB)	Requirement (dB)	Impedance
5200	-9.32	-8	$20.88 \Omega + 10.83 j\Omega$
5400	-10.98	-8	$76.16 \Omega - 0.57 j\Omega$
5600	-13.52	-8	$31.86 \Omega - 9.17 j\Omega$
5800	-13.05	-8	$57.79 \Omega + 20.13 j\Omega$

## 6.3 MECHANICAL DIMENSIONS

Frequency (MHz)	L (mm)		W (mm)		L <sub>t</sub> (mm)		W <sub>t</sub> (mm)	
	Required	Measured	Required	Measured	Required	Measured	Required	Measured
5800	40.39 ± 0.13	-	20.19 ± 0.13	-	81.03 ± 0.13	-	61.98 ± 0.13	-





**Figure 1: Validation Waveguide Dimensions**

## 7 VALIDATION MEASUREMENT

The IEEE Std. 1528 and CEI/IEC 62209 standards state that the system validation measurements must be performed using a reference waveguide meeting the fore mentioned return loss and mechanical dimension requirements. The validation measurement must be performed with the matching layer placed in the open end of the waveguide, with the waveguide and matching layer in direct contact with the phantom shell.

### 7.1 HEAD LIQUID MEASUREMENT

Frequency MHz	Relative permittivity ( $\epsilon_r'$ )		Conductivity ( $\sigma$ ) S/m	
	required	measured	required	measured
5000	36.2 $\pm$ 10 %		4.45 $\pm$ 10 %	
5100	36.1 $\pm$ 10 %		4.56 $\pm$ 10 %	
5200	36.0 $\pm$ 10 %	34.60	4.66 $\pm$ 10 %	4.55
5300	35.9 $\pm$ 10 %		4.76 $\pm$ 10 %	
5400	35.8 $\pm$ 10 %	34.02	4.86 $\pm$ 10 %	4.88
5500	35.6 $\pm$ 10 %		4.97 $\pm$ 10 %	
5600	35.5 $\pm$ 10 %	33.46	5.07 $\pm$ 10 %	5.25
5700	35.4 $\pm$ 10 %		5.17 $\pm$ 10 %	
5800	35.3 $\pm$ 10 %	32.78	5.27 $\pm$ 10 %	5.64
5900	35.2 $\pm$ 10 %		5.38 $\pm$ 10 %	
6000	35.1 $\pm$ 10 %		5.48 $\pm$ 10 %	

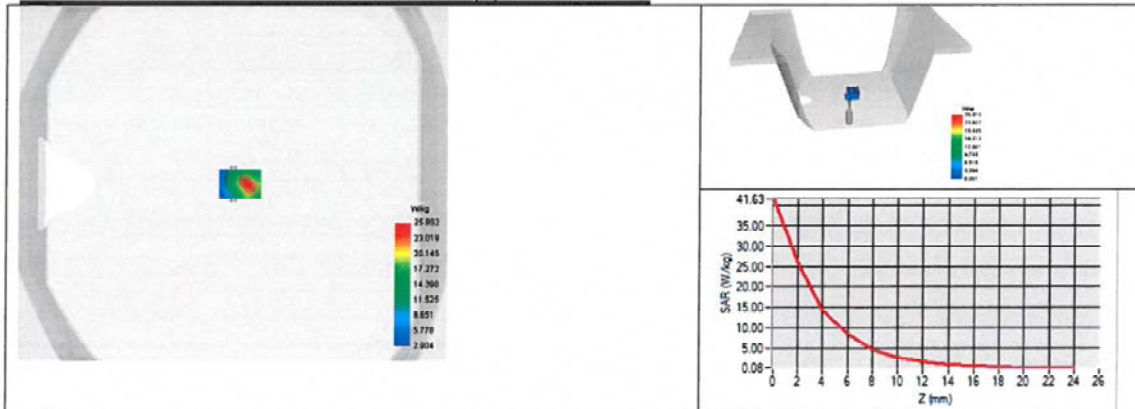
### 7.2 SAR MEASUREMENT RESULT WITH HEAD LIQUID

At those frequencies, the target SAR value can not be generic. Hereunder is the target SAR value defined by MVG, within the uncertainty for the system validation. All SAR values are normalized to 1 W net power. In bracket, the measured SAR is given with the used input power.

Software	OPENSAR V5
Phantom	SN 13/09 SAM68
Probe	SN 41/18 EPG0333
Liquid	Head Liquid Values 5200 MHz: eps' :34.60 sigma : 4.55 Head Liquid Values 5400 MHz: eps' :34.02 sigma : 4.88 Head Liquid Values 5600 MHz: eps' :33.46 sigma : 5.25 Head Liquid Values 5800 MHz: eps' :32.78 sigma : 5.64
Distance between dipole waveguide and liquid	0 mm
Area scan resolution	dx=8mm/dy=8mm
Zoon Scan Resolution	dx=4mm/dy=4m/dz=2mm
Frequency	5200 MHz 5400 MHz 5600 MHz 5800 MHz
Input power	20 dBm
Liquid Temperature	20 +/- 1 °C
Lab Temperature	20 +/- 1 °C
Lab Humidity	30-70 %

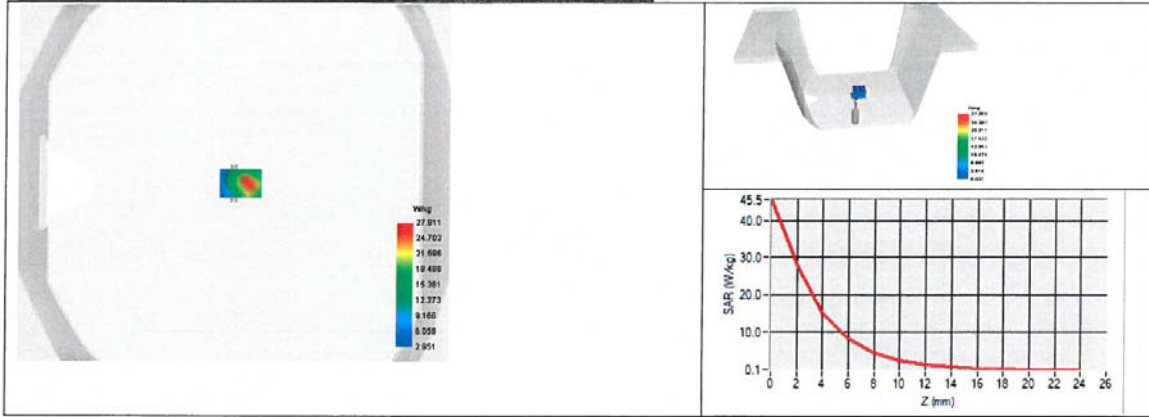
Frequency (MHz)	1 g SAR (W/kg)		10 g SAR (W/kg)	
	required	measured	required	measured
5200	159.00	151.11 (15.11)	56.90	54.03 (5.40)
5400	166.40	159.92 (15.99)	58.43	56.78 (5.68)
5600	173.80	165.99 (16.60)	59.97	58.35 (5.83)
5800	181.20	176.86 (17.69)	61.50	61.84 (6.18)

### SAR MEASUREMENT PLOTS @ 5200 MHz

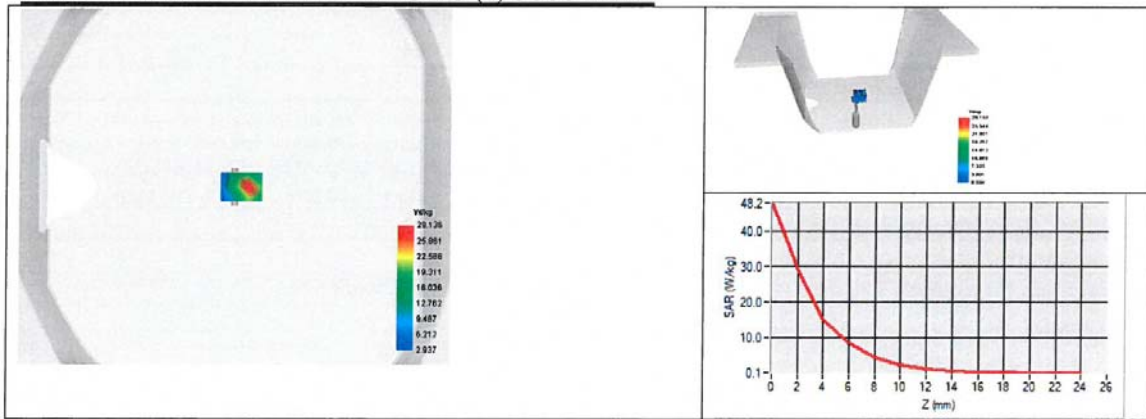




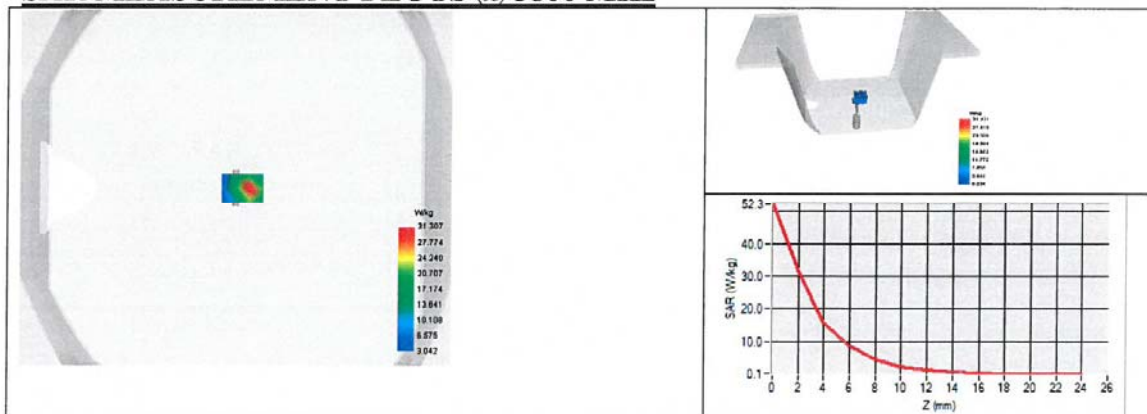
**SAR MEASUREMENT PLOTS @ 5400 MHz**



**SAR MEASUREMENT PLOTS @ 5600 MHz**



**SAR MEASUREMENT PLOTS @ 5800 MHz**





### 7.3 BODY LIQUID MEASUREMENT

Frequency MHz	Relative permittivity ( $\epsilon_r'$ )		Conductivity ( $\sigma$ ) S/m	
	required	measured	required	measured
5200	49.0 $\pm$ 10 %	45.25	5.30 $\pm$ 10 %	5.42
5300	48.9 $\pm$ 10 %		5.42 $\pm$ 10 %	
5400	48.7 $\pm$ 10 %	45.09	5.53 $\pm$ 10 %	5.80
5500	48.6 $\pm$ 10 %		5.65 $\pm$ 10 %	
5600	48.5 $\pm$ 10 %	44.84	5.77 $\pm$ 10 %	6.20
5800	48.2 $\pm$ 10 %	44.59	6.00 $\pm$ 10 %	6.56

### 7.4 SAR MEASUREMENT RESULT WITH BODY LIQUID

Software	OPENSAR V5
Phantom	SN 13/09 SAM68
Probe	SN 41/18 EPGO333
Liquid	Body Liquid Values 5200 MHz: $\epsilon_r'$ :45.25 sigma : 5.42 Body Liquid Values 5400 MHz: $\epsilon_r'$ :45.09 sigma : 5.80 Body Liquid Values 5600 MHz: $\epsilon_r'$ :44.84 sigma : 6.20 Body Liquid Values 5800 MHz: $\epsilon_r'$ :44.59 sigma : 6.56
Distance between dipole waveguide and liquid	0 mm
Area scan resolution	dx=8mm/dy=8mm
Zoon Scan Resolution	dx=4mm/dy=4m/dz=2mm
Frequency	5200 MHz 5400 MHz 5600 MHz 5800 MHz
Input power	20 dBm
Liquid Temperature	20 +/- 1 °C
Lab Temperature	20 +/- 1 °C
Lab Humidity	30-70 %

Frequency (MHz)	1 g SAR (W/kg)	10 g SAR (W/kg)
	measured	measured
5200	150.13 (15.01)	55.47 (5.55)
5400	152.16 (15.22)	55.69 (5.57)
5600	154.92 (15.49)	56.02 (5.60)
5800	158.10 (15.81)	54.64 (5.46)

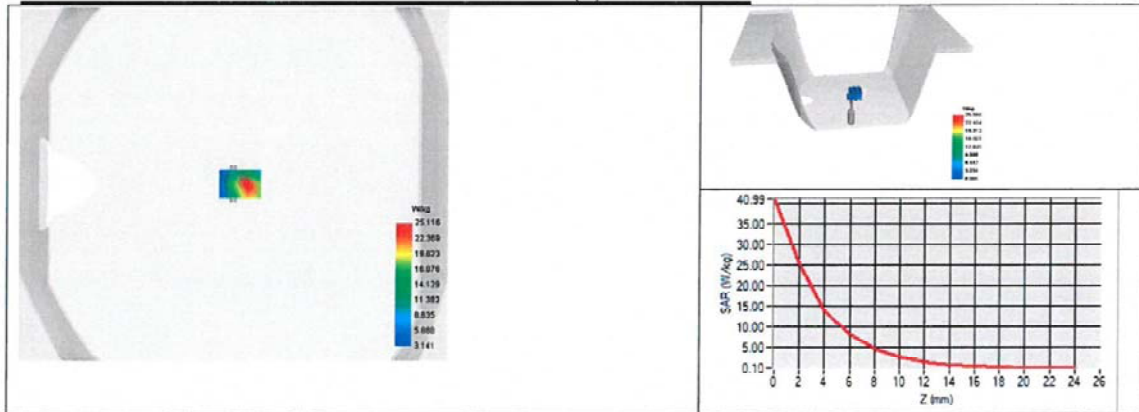




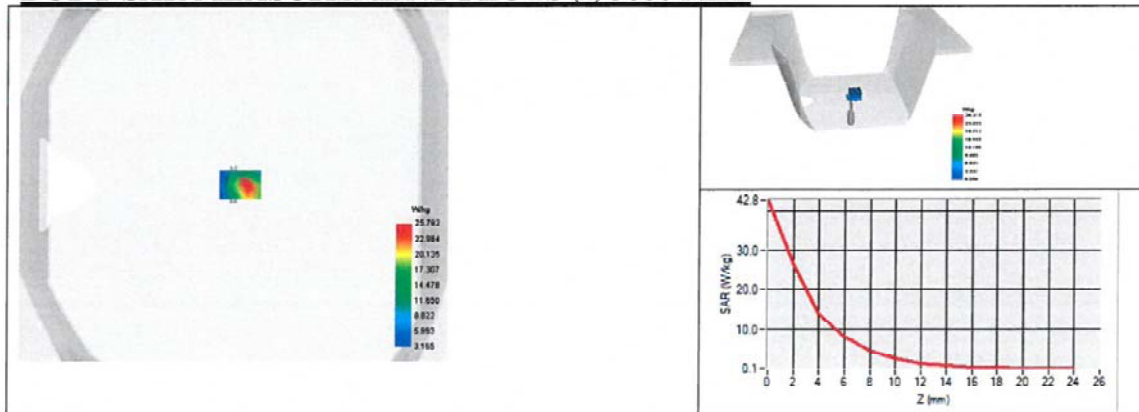
**BODY SAR MEASUREMENT PLOTS @ 5200 MHz**



**BODY SAR MEASUREMENT PLOTS @ 5400 MHz**

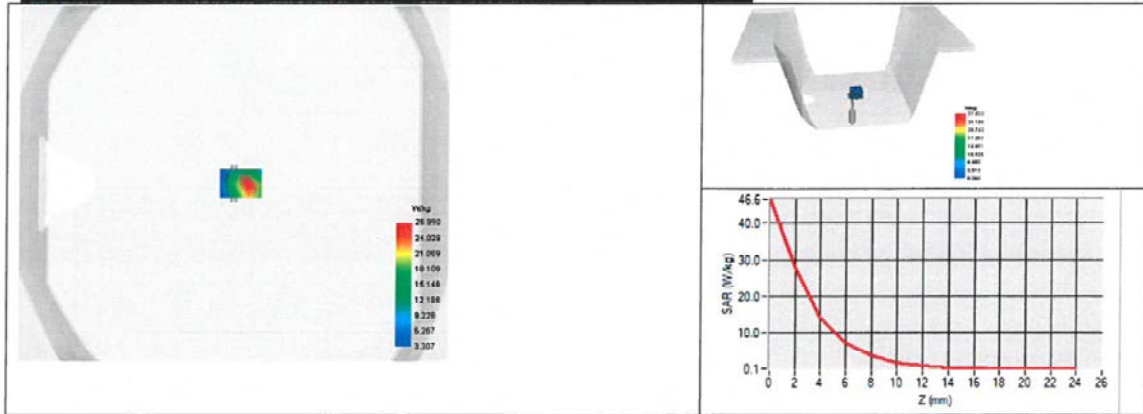


**BODY SAR MEASUREMENT PLOTS @ 5600 MHz**





### BODY SAR MEASUREMENT PLOTS @ 5800 MHz





## 8 LIST OF EQUIPMENT

Equipment Summary Sheet				
Equipment Description	Manufacturer / Model	Identification No.	Current Calibration Date	Next Calibration Date
Flat Phantom	MVG	SN-13/09-SAM68	Validated. No cal required.	Validated. No cal required.
COMOSAR Test Bench	Version 3	NA	Validated. No cal required.	Validated. No cal required.
Network Analyzer	Rohde & Schwarz ZVM	100203	05/2019	05/2022
Network Analyzer – Calibration kit	Rohde & Schwarz ZV-Z235	101223	05/2019	05/2022
Calipers	Mitutoyo	SN 0009732	10/2019	10/2022
Reference Probe	MVG	EPGO333 SN 41/18	05/2020	05/2021
Multimeter	Keithley 2000	1160271	02/2020	02/2023
Signal Generator	Rohde & Schwarz SMB	106589	04/2019	04/2022
Amplifier	Aethercomm	SN 046	Characterized prior to test. No cal required.	Characterized prior to test. No cal required.
Power Meter	NI-USB 5680	170100013	05/2019	05/2022
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	150798832	11/2017	11/2020