



SCOPE OF ACCREDITATION TO ISO/IEC 17025:2005,  
& ANSI/NCSL Z540-1-1994 & ANSI/NCSL Z540.3:2006

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CALIBRATION

Valid To: October 31, 2013

Certificate Number: 1964.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following calibrations<sup>1</sup>:

I. Dimensional

Parameter/Equipment	Range	CMC <sup>2,4</sup> (±)	Comments
Gage blocks	(0.01 to 4) in (0.50 to 100.00) mm	(2 + L) µin (0.5 + 0.0015L) µm	Electromechanical comparison
Cylindrical Ring Gages	Up to 4 in	(6 + 12L) µin	Gage blocks, internal comparison
Cylindrical Plug Gages	Up to 2 in	(26 + 6L) µin	Gage blocks
Thread Measuring Wires	(4 to 80) TPI	15 µin	Mechanical comparison
Thread Plug Gages Pitch and Major Diameter	(4 to 80) TPI	60 µin	3 wire method

Parameter/Equipment	Range	CMC <sup>2,4,8</sup> (±)	Comments
Micrometers –			
Outside	Up to 12 in	(35 + 6L) μin	Gage blocks
Depth	Up to 12 in	(40 + 6L) μin	
Inside	Up to 12 in	(25 + 6L) μin	
Calipers	Up to 60 in	(320 + 6L) μin	Gage blocks, ring gage
Height Gages	Up to 60 in	(320 + 6L) μin	Gage blocks
Dial/Digital Indicators	Up to 1 in	33 μin	Gage blocks
Surface Plate <sup>3</sup>	(60 x 96) in	12 √D μin	Electronic level D = Diagonal
Connector Gage Masters	Up to 0.25 in Up to 50 μin	200 μin 16 μin	Dial indicator, optical flat
Torque Moment Arms	Up to 24 in	(150 + 50L) μin	Gage blocks, electronic gage amplifier
Length Measurement	Up to 12 in (12 to 60) in	(10 + 10L) μin (150 + 12L) μin	Laser interferometer
Angle –			
Autocollimators	Up to 1000 arc s	(0.3 % + 0.4) arc s	Laser interferometer
Angle Generator	Up to 1000 arc s	(0.27 %) arc s	
Electronic Level	Up to 200 arc s Up to 1000 arc s	0.8 arc s 3.0 arc s	
Angle Gage Blocks	1 arc s to 45 degrees	1.0 arc s	Angle gage blocks; Autocollimator

Parameter/Equipment	Range	CMC <sup>2, 4, 8</sup> (±)	Comments
Optical Wedge	Up to 30 arc s	0.6 arc s	Autocollimator
Electronic Gage Amplifiers	Up to 0.1 in	10 µin	Gage blocks
Alignment Collimator <sup>5</sup>	2 ft to Infinity	1.3 arc s	Optical wedge
Theodolite/Transit/ Alignment Telescope – Collimation <sup>5</sup>	Infinity Focus	1.1 arc s	Alignment collimator
Line of Sight <sup>5</sup>	2 ft to Infinity	1.6 arc s	
Trunnion Axis	(60 to 135) °	1.2 arc s	

## II. Electrical – DC/Low Frequency

Parameter/Equipment	Range	CMC <sup>2, 6, 7</sup> (±)	Comments
DC Voltage <sup>3</sup> – Fixed Points	0.1 V 1 V 10 V 100 V 1000 V  (2 to 60) kV  (10 to 220) mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V 220 V to 1.1 kV	0.76 µV/V 0.22 µV/V 0.22 µV/V 0.50 µV/V 0.73 µV/V  0.004 %  6 µV/V + 0.4 µV 3.5 µV/V + 0.7 µV 2.5 µV/V + 2.5 µV 2.4 µV/V + 4 µV 3.5 µV/V + 40 µV 4.5 µV/V + 400 µV	Fluke 732B HP 34420A NVM HP 3458A DMM Data proof 160 scanner Fluke 752A  PTB voltage divider Agilent 3458A DMM Fluke 5720A calibrator

Parameter/Equipment	Range	CMC <sup>2, 8</sup> (±)	Comments
Resistance – Measure <sup>3</sup>	(0.001 to 0.002) Ω (0.003 to 0.005) Ω (0.006 to 0.009) Ω (0.01 to 0.02) Ω (0.03 to 0.05) Ω (0.06 to 0.09) Ω (0.3 to 0.5) Ω (0.6 to 0.9) Ω (1 to 13) Ω 14 Ω to 1 kΩ (1.1 to 9) kΩ (11 to 100) kΩ 200 kΩ to 1 MΩ (2 to 10) MΩ (11 to 100) MΩ (200 to 900) MΩ	1.4 μΩ/Ω 3.4 μΩ/Ω 2.4 μΩ/Ω 1.5 μΩ/Ω 3.4 μΩ/Ω 2.4 μΩ/Ω 1.4 μΩ/Ω 1.0 μΩ/Ω 0.17 μΩ/Ω 0.38 μΩ/Ω 0.40 μΩ/Ω 0.45 μΩ/Ω 0.84 μΩ/Ω 1.8 μΩ/Ω 4.1 μΩ/Ω 12 μΩ/Ω	Guideline 6675A, 6623; L&N standard resistors; ESI SR 1010, SR 1050; Hart 7009 oil bath; MI 9300 air bath
Resistance – Measure, <sup>3</sup> Fixed Points	0.1 Ω 0.2 Ω 1 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ 1 GΩ	0.62 μΩ/Ω 0.64 μΩ/Ω 0.17 μΩ/Ω 0.17 μΩ/Ω 0.38 μΩ/Ω 0.38 μΩ/Ω 0.25 μΩ/Ω 12 μΩ/Ω	Guideline 6675A, 6623; L&N standard resistors; ESI SR 1010, SR 1050; Hart 7009 oil bath; MI 9300 air bath
High Resistance – Measure	(1 to 10) GΩ (10 to 100) GΩ 100 GΩ to 1 TΩ (1 to 10) TΩ (10 to 100) TΩ 100 TΩ to 1 PΩ (1 to 10) PΩ	0.08 % 0.12 % 0.23 % 0.35 % 0.58 % 1.2 % 12 %	Guideline 6500A terohmmeter
Capacitance – Measure <sup>3</sup>  @ 1 kHz	(3, 4) pF (5 to 9) pF (10, 20, 30) pF (40 to 100) pF (300 to 400) pF (500 to 600) pF (700 to 800) pF (900 to 1000) pF (1 nF)	3.7 μF/F 3.6 μF/F 3.6 μF/F 3.5 μF/F 3.5 μF/F 3.6 μF/F 3.5 μF/F 3.6 μF/F	Andeen Hagerling 2500 A capacitance bridge, Andeen Hagerling 1100 – 10 PFD & 100 PFD standard capacitors, GR 1404A 1000 PFD standard capacitor

Parameter/Frequency	Range	CMC <sup>2</sup> (±)	Comments
Capacitance – Measure <sup>3</sup> (cont) @ 1 kHz, Fixed Points	1 pF 2 pF 200 pF	4.1 μF/F 3.8 μF/F 3.6 μF/F	Andeen Hagerling 2500 A capacitance bridge, Andeen Hagerling 1100 – 10 PFD & 100 PFD standard capacitors, GR 1404A 1000 PFD standard capacitor
Capacitance – Measure <sup>3</sup> @ 1 kHz  Fixed Points	(2 to 4) nF (6 to 10) nF (30 to 40) nF (60 to 100) nF (300 to 400) nF (600 to 1200) nF (1.2 μF)  5 nF 20 nF 50 nF 200 nF 500 nF	3.6 μF/F 3.7 μF/F 3.9 μF/F 4.7 μF/F 7.4 μF/F 15 μF/F  3.7 μF/F 3.9 μF/F 4.7 μF/F 7.4 μF/F 15 μF/F	Andeen Hagerling 2500A capacitance bridge, Andeen Hagerling 1100 – 10 PFD & 100 PFD standard capacitors, GR 1404A 1000 PFD standard capacitor
Capacitance – Generate, Fixed Points  0.05 kHz 0.1 kHz 0.4 kHz 0.8 kHz 1 kHz 2 kHz 6 kHz 8 kHz 10 kHz 16 kHz 20 kHz	10 pF 10 pF 10 pF 10 pF 10 pF 10 pF 10 pF 10 pF 10 pF 10 pF 10 pF 10 pF	3.4 μF/F 1.6 μF/F 0.48 μF/F 0.35 μF/F 0.33 μF/F 0.32 μF/F 0.55 μF/F 0.75 μF/F 1.1 μF/F 2.3 μF/F 3.5 μF/F	Standard capacitors

Parameter/Frequency	Range	CMC <sup>2, 8</sup> (±)	Comments
Capacitance – Generate, Fixed Points (cont)			
0.05 kHz	100 pF	1.9 µF/F	Standard capacitors
0.1 kHz	100 pF	1.0 µF/F	
0.4 kHz	100 pF	0.54 µF/F	
0.8 kHz	100 pF	0.46 µF/F	
1 kHz	100 pF	0.29 µF/F	
2 kHz	100 pF	0.28 µF/F	
6 kHz	100 pF	0.45 µF/F	
8 kHz	100 pF	0.81 µF/F	
10 kHz	100 pF	0.94 µF/F	
16 kHz	100 pF	2.1 µF/F	
20 kHz	100 pF	2.7 µF/F	
0.1 kHz	1000 pF	3.7 µF/F	
0.4 kHz	1000 pF	2.7 µF/F	
1 kHz	1000 pF	2.3 µF/F	
1 kHz	1 pF	0.0030 %	
10 kHz	1 pF	0.0033 %	
50 kHz	1 pF	0.0055 %	
100 kHz	1 pF	0.0083 %	
500 kHz	1 pF	0.035 %	
1 MHz	1 pF	0.071 %	
2 MHz	1 pF	0.16 %	
3 MHz	1 pF	0.28 %	
4 MHz	1 pF	0.38 %	
5 MHz	1 pF	0.51 %	
6 MHz	1 pF	0.66 %	
7 MHz	1 pF	0.82 %	
8 MHz	1 pF	1.0 %	
9 MHz	1 pF	1.2 %	
10 MHz	1 pF	1.4 %	
1 kHz	10 pF	0.0029 %	
10 kHz	10 pF	0.0033 %	
50 kHz	10 pF	0.0033 %	
100 kHz	10 pF	0.0033 %	
500 kHz	10 pF	0.0033 %	
1 MHz	10 pF	0.0033 %	
2 MHz	10 pF	0.0054 %	
3 MHz	10 pF	0.010 %	
4 MHz	10 pF	0.017 %	

Parameter/Frequency	Range	CMC <sup>2, 8</sup> (±)	Comments
Capacitance – Generate, Fixed Points (cont)			
5 MHz	10 pF	0.027 %	Standard capacitor set
6 MHz	10 pF	0.039 %	
7 MHz	10 pF	0.053 %	
8 MHz	10 pF	0.070 %	
9 MHz	10 pF	0.090 %	
10 MHz	10 pF	0.11 %	
1 kHz	100 pF	0.0029 %	
10 kHz	100 pF	0.0033 %	
50 kHz	100 pF	0.0033 %	
100 kHz	100 pF	0.0033 %	
500 kHz	100 pF	0.0033 %	
1 MHz	100 pF	0.0037 %	
2 MHz	100 pF	0.0059 %	
3 MHz	100 pF	0.010 %	
4 MHz	100 pF	0.018 %	
5 MHz	100 pF	0.027 %	
6 MHz	100 pF	0.039 %	
7 MHz	100 pF	0.054 %	
8 MHz	100 pF	0.070 %	
9 MHz	100 pF	0.090 %	
10 MHz	100 pF	0.11 %	
1 kHz	1000 pF	0.0029 %	
10 kHz	1000 pF	0.0033 %	
50 kHz	1000 pF	0.0033 %	
100 kHz	1000 pF	0.0033 %	
500 kHz	1000 pF	0.0033 %	
1 MHz	1000 pF	0.0037 %	
2 MHz	1000 pF	0.0059 %	
3 MHz	1000 pF	0.010 %	
4 MHz	1000 pF	0.018 %	
5 MHz	1000 pF	0.027 %	
6 MHz	1000 pF	0.039 %	
7 MHz	1000 pF	0.053 %	
8 MHz	1000 pF	0.070 %	
9 MHz	1000 pF	0.090 %	
10 MHz	1000 pF	0.11 %	

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Electrical Calibration of Thermocouple Indicating Devices <sup>3</sup> –			
Type E	-270 °C to -265 °C -264 °C to -240 °C -239 °C to -212 °C -211 °C to 1200 °C	0.30 °C 0.10 °C 0.03 °C 0.03 °C	Calibrator, ice bath
Type J	-210 °C to -197 °C -196 °C to 1200 °C	0.04 °C 0.03 °C	
Type K	-270 °C to -263 °C -262 °C to -251 °C -250 °C to -234 °C -233 °C to -195 °C -194 °C to 1372 °C	0.30 °C 0.15 °C 0.10 °C 0.05 °C 0.03 °C	
Type N	-270 °C to -253 °C -252 °C to -239 °C -238 °C to -226 °C -225 °C to -201 °C -200 °C to -73 °C -72 °C to 1300 °C	0.28 °C 0.14 °C 0.09 °C 0.07 °C 0.05 °C 0.03 °C	
Type R	-50 °C to -17 °C -16 °C to 10 °C 11 °C to 1768 °C	0.13 °C 0.09 °C 0.07 °C	
Type S	-50 °C to 38 °C 37 °C to 1768 °C	0.09 °C 0.07 °C	
Type T	-270 °C to -266 °C -265 °C to -259 °C -258 °C to -196 °C -195 °C to -18 °C -17 °C to 400 °C	0.30 °C 0.14 °C 0.07 °C 0.03 °C 0.02 °C	

Parameter/Equipment	Range	CMC <sup>2, 8</sup> (±)	Comments
DC Current – Generate and Measure <sup>3</sup>	1 µA to 30 mA (31 to 100) mA (101 to 300) mA (301 to 400) mA (500 to 799) mA (800 to 900) mA 901 mA to 15 A (16 to 50) A (51 to 70) A (71 to 100) A (101 to 400) A	4 µA/A 5 µA/A 6 µA/A 13 µA/A 11 µA/A 9 µA/A 8 µA/A 13 µA/A 18 µA/A 24 µA/A 30 µA/A	Stable DC source standard resistor, voltmeter
Inductance – Generate and Measure	100 µH @ 100 Hz 1 kHz 10 kHz  1 mH @ 100 Hz 1 kHz 10 kHz  10 mH @ 1 kHz 10 kHz  100 mH @ 100 Hz 1 kHz 10 kHz  1 H @ (100, 400) Hz 1 kHz  10 H @ (100, 400) Hz 1 kHz	0.015 % 0.008 % 0.015 %  0.010 % 0.007 % 0.015 %  0.007 % 0.013 %  0.009 % 0.007 % 0.02 %  0.008 % 0.007 %  0.009 % 0.008 %	Quadtech 7600 plus LCR meter, GR 1482B,E,H,L,P,T standard inductors

Parameter/Range	Frequency	CMC <sup>2, 8</sup> (±)	Comments	
AC Voltage Flatness – Measure	0.45 V	0.3 MHz	0.02 %	Ballantine thermal voltage converters: 1395B-0.4-09 1395B-1-09 1395B-3-09
		1 MHz	0.04 %	
		3 MHz	0.03 %	
		10 MHz	0.04 %	
		30 MHz	0.05 %	
		50 MHz	0.08 %	
		80 MHz	0.16 %	
		100 MHz	0.36 %	
		1 V	0.3 MHz	
	1 MHz		0.04 %	
	3 MHz		0.03 %	
	10 MHz		0.04 %	
	30 MHz		0.05 %	
	50 MHz		0.08 %	
	80 MHz		0.16 %	
	100 MHz		0.30 %	
	3 V		0.3 MHz	
		1 MHz	0.04 %	
		3 MHz	0.03 %	
		10 MHz	0.04 %	
		30 MHz	0.05 %	
		50 MHz	0.08 %	
		80 MHz	0.16 %	
		100 MHz	0.24 %	

Parameter/Range	Frequency	CMC <sup>2, 8</sup> (±)	Comments
AC Voltage – Generate and Measure <sup>3</sup>	2 mV	10 Hz	Fluke 792A AC/DC thermal transfer standard
		20 Hz	
		40 Hz	
		100 Hz	
		1 kHz	
		10 kHz	
		20 kHz	
		50 kHz	
		100 kHz	
		300 kHz	
		500 kHz	
		800 kHz	
	1 MHz		
	6 mV	10 Hz	
		20 Hz	
		40 Hz	
		100 Hz	
		1 kHz	
		10 kHz	
		20 kHz	
		50 kHz	
		100 kHz	
		300 kHz	
		500 kHz	
		800 kHz	
	1 MHz		
	10 mV	10 Hz	
		20 Hz	
		40 Hz	
		100 Hz	
		1 kHz	
		10 kHz	
		20 kHz	
		50 kHz	
		100 kHz	
		300 kHz	
500 kHz			
800 kHz			
1 MHz			

Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments
AC Voltage – Generate and Measure <sup>3</sup> (cont)			
20 mV	10 Hz	63 μV/V	Fluke 792A AC/DC thermal transfer standard
	20 Hz	52 μV/V	
	40 Hz	49 μV/V	
	100 Hz	51 μV/V	
	1 kHz	55 μV/V	
	10 kHz	50 μV/V	
	20 kHz	53 μV/V	
	50 kHz	49 μV/V	
	100 kHz	52 μV/V	
	300 kHz	58 μV/V	
	500 kHz	59 μV/V	
	800 kHz	76 μV/V	
	1 MHz	94 μV/V	
60 mV	10 Hz	36 μV/V	
	20 Hz	29 μV/V	
	40 Hz	28 μV/V	
	100 Hz	25 μV/V	
	1 kHz	27 μV/V	
	10 kHz	27 μV/V	
	20 kHz	26 μV/V	
	50 kHz	27 μV/V	
	100 kHz	29 μV/V	
	300 kHz	34 μV/V	
	500 kHz	37 μV/V	
	800 kHz	43 μV/V	
	1 MHz	51 μV/V	
100 mV	10 Hz	22 μV/V	
	20 Hz	19 μV/V	
	40 Hz	21 μV/V	
	100 Hz	18 μV/V	
	1 kHz	19 μV/V	
	10 kHz	18 μV/V	
	20 kHz	19 μV/V	
	50 kHz	20 μV/V	
	100 kHz	19 μV/V	
	300 kHz	21 μV/V	
	500 kHz	18 μV/V	
	800 kHz	29 μV/V	
	1 MHz	34 μV/V	

Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments	
AC Voltage – Generate and Measure <sup>3</sup> (cont)	200 mV	10 Hz	16 μV/V	Fluke 792A AC/DC thermal transfer standard
		20 Hz	15 μV/V	
		40 Hz	15 μV/V	
		100 Hz	15 μV/V	
		1 kHz	15 μV/V	
		10 kHz	14 μV/V	
		20 kHz	14 μV/V	
		50 kHz	14 μV/V	
		100 kHz	15 μV/V	
		300 kHz	15 μV/V	
		500 kHz	17 μV/V	
		800 kHz	23 μV/V	
		1 MHz	29 μV/V	
		600 mV	10 Hz	
	20 Hz		11 μV/V	
	40 Hz		11 μV/V	
	100 Hz		11 μV/V	
	1 kHz		11 μV/V	
	10 kHz		11 μV/V	
	20 kHz		11 μV/V	
	50 kHz		11 μV/V	
	100 kHz		11 μV/V	
	300 kHz		13 μV/V	
	500 kHz		17 μV/V	
	800 kHz		20 μV/V	
	1 MHz		26 μV/V	
	1 V		10 Hz	
		20 Hz	7 μV/V	
		40 Hz	7 μV/V	
		100 Hz	8 μV/V	
		1 kHz	7 μV/V	
		10 kHz	7 μV/V	
		20 kHz	9 μV/V	
		50 kHz	10 μV/V	
		100 kHz	11 μV/V	
		300 kHz	17 μV/V	
500 kHz		25 μV/V		
800 kHz		37 μV/V		
1 MHz		42 μV/V		

Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments
AC Voltage – Generate and Measure <sup>3</sup> (cont)			
2 V	10 Hz	8 μV/V	Fluke 792A AC/DC thermal transfer standard
	20 Hz	8 μV/V	
	40 Hz	8 μV/V	
	100 Hz	8 μV/V	
	1 kHz	7 μV/V	
	10 kHz	7 μV/V	
	20 kHz	8 μV/V	
	50 kHz	8 μV/V	
	100 kHz	8 μV/V	
	300 kHz	10 μV/V	
	500 kHz	15 μV/V	
	800 kHz	20 μV/V	
	1 MHz	25 μV/V	
	6 V	10 Hz	
20 Hz		7 μV/V	
40 Hz		7 μV/V	
100 Hz		8 μV/V	
1 kHz		8 μV/V	
10 kHz		8 μV/V	
20 kHz		8 μV/V	
50 kHz		9 μV/V	
100 kHz		9 μV/V	
300 kHz		11 μV/V	
500 kHz		15 μV/V	
800 kHz		19 μV/V	
1 MHz		24 μV/V	
10 V		10 Hz	14 μV/V
	20 Hz	7 μV/V	
	40 Hz	7 μV/V	
	100 Hz	7 μV/V	
	1 kHz	7 μV/V	
	10 kHz	9 μV/V	
	20 kHz	9 μV/V	
	50 kHz	10 μV/V	
	100 kHz	12 μV/V	
	300 kHz	13 μV/V	
	500 kHz	17 μV/V	
	800 kHz	20 μV/V	
	1 MHz	26 μV/V	

Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments
AC Voltage – Generate and Measure <sup>3</sup> (cont)			
20 V	10 Hz	13 μV/V	Fluke 792A AC/DC thermal transfer standard
	20 Hz	8 μV/V	
	40 Hz	7 μV/V	
	100 Hz	7 μV/V	
	1 kHz	8 μV/V	
	10 kHz	8 μV/V	
	20 kHz	9 μV/V	
	50 kHz	9 μV/V	
	100 kHz	10 μV/V	
	300 kHz	11 μV/V	
	500 kHz	15 μV/V	
	800 kHz	19 μV/V	
	1 MHz	24 μV/V	
	60 V	10 Hz	
20 Hz		10 μV/V	
40 Hz		9 μV/V	
100 Hz		9 μV/V	
1 kHz		9 μV/V	
10 kHz		9 μV/V	
20 kHz		10 μV/V	
50 kHz		10 μV/V	
100 kHz		13 μV/V	
300 kHz		13 μV/V	
100 V		10 Hz	16 μV/V
	20 Hz	12 μV/V	
	40 Hz	10 μV/V	
	100 Hz	10 μV/V	
	1 kHz	9 μV/V	
	10 kHz	10 μV/V	
	20 kHz	10 μV/V	
	50 kHz	10 μV/V	
	100 kHz	14 μV/V	
200 V	10 Hz	16 μV/V	
	20 Hz	12 μV/V	
	40 Hz	10 μV/V	
	100 Hz	10 μV/V	
	1 kHz	11 μV/V	
	10 kHz	11 μV/V	
	20 kHz	11 μV/V	
	50 kHz	11 μV/V	
	100 kHz	17 μV/V	

Parameter/Range	Frequency	CMC <sup>2, 8</sup> (±)	Comments
AC Voltage – Generate and Measure <sup>3</sup> (cont)			
600 V	10 Hz 20 Hz 40 Hz 100 Hz 1 kHz 10 kHz 20 kHz 50 kHz 100 kHz	17 µV/V 12 µV/V 11 µV/V 11 µV/V 12 µV/V 12 µV/V 12 µV/V 13 µV/V 24 µV/V	Fluke 792A AC/DC thermal transfer standard
1000 V	10 Hz 20 Hz 40 Hz 100 Hz 1 kHz 10 kHz 20 kHz 50 kHz 100 kHz	17 µV/V 12 µV/V 11 µV/V 11 µV/V 12 µV/V 12 µV/V 16 µV/V 18 µV/V 29 µV/V	
(2 to 80) kV	60 Hz	0.25 %	
AC Current – Generate and Measure <sup>3</sup>			
10 mA	20 Hz 400 Hz 1 kHz 5 kHz 20 kHz 50 kHz	31 µA/A 18 µA/A 18 µA/A 18 µA/A 18 µA/A 29 µA/A	Holt HCS-1 AC shunts, Fluke 5720A/5725A, HP 3458A DMM, Wavetek 4920, Fluke 792A
20 mA	20 Hz 400 Hz 1 kHz 5 kHz	31 µA/A 18 µA/A 18 µA/A 18 µA/A	
50 mA	20 Hz 400 Hz 1 kHz 5 kHz	31 µA/A 18 µA/A 18 µA/A 18 µA/A	

Parameter/Equipment	Range	CMC <sup>2,7</sup> (±)	Comments	
AC Current – Generate and Measure <sup>3</sup>				
100 mA	20 Hz 400 Hz 1 kHz 5 kHz 20 kHz 50 kHz	32 μA/A 21 μA/A 21 μA/A 21 μA/A 21 μA/A 41 μA/A	Holt HCS-1 AC shunts, Fluke 5720A/5725A, HP 3458A DMM, Wavetek 4920, Fluke 792A	
200 mA	20 Hz 400 Hz 1 kHz 5 kHz	34 μA/A 22 μA/A 22 μA/A 22 μA/A		
500 mA	20 Hz 400 Hz 1 kHz 5 kHz	36 μA/A 23 μA/A 23 μA/A 23 μA/A		
1 A	20 Hz 400 Hz 1 kHz 5 kHz 20 kHz 50 kHz	38 μA/A 25 μA/A 25 μA/A 25 μA/A 25 μA/A 55 μA/A		
2 A	20 Hz 400 Hz 1 kHz 5 kHz	42 μA/A 27 μA/A 27 μA/A 27 μA/A		
5 A	20 Hz 400 Hz 1 kHz 5 kHz	54 μA/A 34 μA/A 34 μA/A 34 μA/A		
10 A	20 Hz 400 Hz 1 kHz 5 kHz 20 kHz	67 μA/A 41 μA/A 41 μA/A 41 μA/A 41 μA/A		
20 A	20 Hz 400 Hz 1 kHz 5 kHz 20 kHz	94 μA/A 58 μA/A 58 μA/A 58 μA/A 58 μA/A		Holt HCS-1 AC shunts, Fluke 5720A/5725A, HP 3458A DMM, Wavetek 4920, Fluke 792A

Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments
Ratio Transformer	400 Hz & 1 kHz	0.000051 % of input	Gertsch 1011
Phase Angle – Generate			
@ 5 V Equal Input	1 Hz to 6.25 kHz (6.25 to 50) kHz (50 to 200) kHz	0.006° 0.012° 0.047°	Clark-Hess 5500-2 phase standard
@ 50 mV to 100 V	1 Hz to 1 kHz (1 to 6.25) kHz (6.25 to 50) kHz (50 to 200) kHz	0.006° 0.012° 0.018° 0.047°	
@ (100 to 120) V	1 Hz to 1 kHz (1 to 6.25) kHz (6.25 to 50) kHz (50 to 200) kHz	0.012° 0.023° 0.035° 0.093°	
Phase Angle – Measure			
@ 10 mV to 350 V	(5 to 10) Hz 10 Hz to 50 kHz (51 to 57) kHz (58 to 66) kHz (67 to 75) kHz (76 to 83) kHz (84 to 92) kHz (93 to 100) kHz 101 kHz 110 kHz 115 kHz 120 kHz 125 kHz 130 kHz 135 kHz 140 kHz 145 kHz 150 kHz 200 kHz 250 kHz 300 kHz 350 kHz 400 kHz 450 kHz 500 kHz	0.23° 0.06° 0.12° 0.13° 0.14° 0.15° 0.16° 0.17° 0.57° 0.62° 0.64° 0.67° 0.69° 0.72° 0.74° 0.77° 0.79° 0.82° 1.1° 1.4° 1.6° 1.9° 2.1° 2.4° 2.6°	Clark-Hess 6000 phase meter

III. Electrical – RF/Microwave

Parameter/Equipment	Range	CMC <sup>2,4</sup> (±)	Comments
AC Current Probe – Transfer Impedance	10 Hz to 200 MHz	1.4 dB	HP 3577A
Antenna Gain –  On Axis Gain, Antenna Factor  Dish Antenna	(0.2 to 26.5) GHz (26.5 to 40) GHz (33 to 50) GHz (50 to 75) GHz (75 to 110) GHz (140 to 220) GHz  (12.4 to 110) GHz	0.15 dB 0.2 dB 0.2 dB 0.25 dB 0.3 dB 0.5 dB  0.27 dB <sup>9</sup>	Agilent/HP 8510C, 8530A, 8517B, V85104A, W85104A Scientific Atlanta 12-2.9, 12-5.8, 12-8.2, 12-12, 12-18, 12-26, 12-33; Narda 642, 643, 645; TRG 861B/383, AB90; FXR M638A, Hughes 45826H-1020, TRG/Custom Microwave WR-5 gain horns, X, Ku, K, Ka, Q, V, W Probes, Leica LT300 Laser Tracker
Counters <sup>3</sup> –  Time Base Accuracy Time Base Aging  Sensitivity	(1, 5, 10) MHz (1, 5, 10) MHz  (0 to -20) dBm (<-20 to -30) dBm (<-30 to -40) dBm (<-40 to -50) dBm	1.3 x 10 <sup>-12</sup> 6.0 x 10 <sup>-13</sup>  0.10 dB 0.15 dB 0.20 dB 0.26 dB	NIST, FMAS, TMAS, Agilent/HP 5370A, 33120A, 83650, 83558A, 8482A, 8385A, 8485A, 8487A, V8486A, W8486A, Datum 4310A
Directional/SWR Bridge <sup>3</sup> –  Reflections/Directivity  Insertion Loss/Linearity	5 Hz to 110 GHz  5 Hz to 67 GHz (67 to 110) GHz	0.03 $\Gamma$ 1.5 dB 0.1 dB 0.2 dB	Agilent/HP 8757D, 355C/D, 85054B, 8481D opt H70

Parameter/Equipment	Range	CMC <sup>2,4,8</sup> (±)	Comments
Directional Coupler <sup>3</sup> –			
Main Line Loss	5 Hz to 67 GHz (67 to 110) GHz	0.1 dB 0.2 dB	Agilent/HP E8361A, 8510C, 8517B V85104A, W85104A
Coupling Loss	5 Hz to 67 GHz (67 to 110) GHz	0.1 dB 0.2 dB	
Reflection	5 Hz to 110 GHz	0.03 $\Gamma$	
Directivity	5 Hz to 110 GHz	1.5 dB	
Function/Pulse Generator <sup>3</sup> –			
Frequency Accuracy	1.0 $\mu$ Hz to 1 GHz	0.1 $\mu$ Hz/Hz	Agilent/HP 53132A
Frequency Stability	10 MHz	$9 \times 10^{-13}$	
AC Output Amplitude	1 mV to 50 V <sub>(p-p)</sub>	0.011 %	Agilent/HP 3458A, 8902
Output Flatness	DC to 100 MHz 100 MHz to 1 GHz	0.3 % 0.5 %	Ballantine 1395B-1 Agilent/HP 8482A
DC Offset	(-20 to +20) VDC	6 $\mu$ V/V	Agilent/HP 3458A
Harmonic Content			
Harmonic Distortion	9 kHz to 1 GHz	1.5 dB	Agilent/HP 8563E, 8903A, 334A, 339A
Non Harmonic	9 kHz to 1 GHz	1.5 dB	
THD	5 Hz to 600 kHz	1.2 dB	
Rise-Fall Time	(10 to 90) %	9.3 ps	Agilent 86100C, 83484A
Pulse Width/Symmetry	1 nsec to 5 sec	1.0 ns	Agilent 53132A
Phase Offset	(0 to 180) $^{\circ}$	1.7 $^{\circ}$	Agilent/HP 5335A
AM Modulation	DC to 100 kHz	2.5 %	Agilent/HP 8902, 8903B

Parameter/Equipment	Range	CMC <sup>2, 8</sup> (±)	Comments
Gaussian Noise <sup>3</sup> –			
Noise Output Power	100 kHz to <18 GHz (18 to 40) GHz	1.2 % 2.6 %	Agilent/HP 8482A/D, 8481A/D, 8485A/D, 8487 A/D
Signal Path Response	9 kHz to <3 GHz (3 to <22) GHz (22 to <50) GHz	1 dB 2.6 dB 3.5 dB	Agilent/HP 8565E
Attenuation	(0 to <10) dB (10 to <30) dB (40 to 50) dB	0.1 dB 0.2 dB 0.3 dB	
Generators – Signal <sup>3</sup>			
Attenuation			
(0 to 10) dB	100 kHz to 50 GHz	0.015 dB	Agilent/HP 8902A measuring receiver with Agilent/HP 11793A microwave converter or 11970 series harmonic mixer, Agilent N5531S
(0 to 20) dB		0.015 dB	
(0 to 30) dB		0.015 dB	
(0 to 40) dB		0.015 dB	
(0 to 50) dB		0.015 dB	
(0 to 60) dB		0.015 dB	
(0 to 70) dB		0.015 dB	
(0 to 80) dB		0.015 dB	
(0 to 90) dB		0.015 dB	
(0 to 100) dB		0.020 dB	
(0 to 110) dB		0.060 dB	
(0 to 120) dB		0.19 dB	
Phase Modulation	0.1 kHz to 50 GHz	1.2 %	
Residual PM	100 kHz to 6.6 GHz (6.6 to 13.2) GHz (13.2 to 31.5) GHz (31.5 to 50) GHz	0.0020 Rad 0.0039 Rad 0.0077 Rad 0.015 Rad	
FM Deviation	100 kHz to 50 GHz	1.2 %	

Parameter/Equipment	Range	CMC <sup>2, 8</sup> (±)	Comments
Generators – Signal <sup>3</sup> (cont)			
Residual FM	100 kHz to 6.6 GHz (6.6 to 13.2) GHz (13.2 to 31) GHz (31 to 50) GHz	<1.7 Hz RMS <3.5 Hz RMS <7 Hz RMS <14 Hz	Agilent/HP 8902, N5531S
AM Depth	0.15 to 10) MHz 10 MHz to 3 GHz (3 to 26.5) GHz (26.5 to 31) GHz (31 to 50) GHz	0.9 % 0.6 % 1.8 % 2.2 % 7.0 %	HP 8902, Agilent 5531S
Residual AM	150 kHz to 50 GHz	0.03 %	HP 8902, Agilent N5531S
Pulse Modulation			
On Off Ratio	100 kHz to 67 GHz	0.6 dB	Agilent E4448A, Agilent 86100C, Agilent 83484A
Rise Fall Time	(10 to 90) %	10 ps	
Pulse Width	50 ps to 1 s	10 ps	
Digital Modulation –			
Magnitude			
EVM For: MSK GMSK, BPSK DQPSK, n/4DQPSK 8 PSK, 16 QAM QPSK, OQPSK	Frequency Span < 100 kHz ≤ 1 MHz > 1 MHz	0.6 % rms 0.7 % rms 1.3 % rms	Agilent/HP 89441A
Phase			
Phase Error for: MSK GMSK, BPSK, DQPSK, n/4DQPSK, 8 PSK, 16 QAM & 32 QAM QPSK, OQPSK	Frequency Span <100 kHz ≤1 MHz >1 MHz	0.6° rms 0.7° rms 0.7° rms	Agilent/HP 89441A
Digital Modulation – Measure			
EVM for FSK	Symbol Rate 3.2 kHz 1.152 MHz	1.1 % rms 1.8 % rms	Agilent/HP 89441A

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Generators – Signal <sup>3</sup> (cont)			
Harmonic Content			
Harmonics	3 Hz to 3 GHz	1.1 dB	Agilent/HP 8565E spectrum analyzer, Agilent/HP 11970 series harmonic converter, Oleson microwave harmonic mixer
Non-Harmonics	(3 to 6.6) GHz	2.0 dB	
Sub Harmonics	(6.6 to 22) GHz	2.5 dB	
	(22 to 26.8) GHz	3.1 dB	
	(26.4 to 31.15) GHz	2.2 dB	
	(31.15 to 50) GHz	3.1 dB	
	(50 to 110) GHz	3.5 dB	
Phase Noise	1 kHz to 1 MHz offset	2.4 dB	Agilent/HP E5052, 3048A
Total Harmonic Distortion	5 Hz to 100 kHz (100 to 600) kHz	1.2 dB 2.0 dB	Agilent/HP 334A, HP 339A, HP 8903A
Frequency/Response Power Accuracy	(0.001 to 18) GHz (18 to 33) GHz (33 to 50) GHz (50 to 75) GHz (75 to 110) GHz	0.10 dB 0.10 dB 0.10 dB 0.12 dB 0.14 dB	Agilent/HP 8482A, 8481A, 8485A, 8487A, V8486A, W8486A
Time Base Aging	(5 to 10) MHz	9 x 10 <sup>-13</sup>	Agilent 53132A, NIST FMAS
Harmonic Mixer Conversion Loss	(18 to 26.5) GHz (26.5 to 40) GHz (33 to 50) GHz (50 to 75) GHz (75 to 110) GHz	1.8 dB 1.8 dB 1.8 dB 1.8 dB 1.8 dB	Agilent/HP 8563E, 8485A, 8487A, V8486A, W8486A Hughes/HP/Millitech thermistor mounts
Network Analyzer <sup>3</sup> – (Scalar/Vector)			
Time Base Accuracy	(1, 5, 10) MHz	9 x 10 <sup>-13</sup>	Agilent/HP 5370A, 3458A, 8482A, 8485A, 8487A, V8487A, W8487A
Source Absolute Accuracy	5 Hz to 110 GHz	0.04 dB	
Source Linearity/Dynamic Accuracy	5 Hz to 110 GHz	0.03 dB	

Parameter/Equipment	Range	CMC <sup>2,4</sup> (±)	Comments
Network Analyzer <sup>3</sup> – (Scalar/Vector) (cont)			
Source Harmonic Content	5 Hz to 3 GHz (3 to 6.6) GHz (6.6 to 22) GHz (22 to 26.8) GHz (26.8 to 31.15) GHz (31.15 to 50) GHz (50 to 110) GHz	1.1 dB 2.0 dB 2.5 dB 3.1 dB 2.2 dB 3.1 dB 3.5 dB	HP 8565E, Agilent E4448A
Receiver Absolute Accuracy	5 Hz to 110 GHz	0.04 dB	Agilent/HP 8482A, 8487A, V8486A, 3458A
Receiver Dynamic Accuracy & Linearity	5 Hz to 110 GHz	0.04 dB	Agilent/HP 355C/D
Corrected Performance Transmission Tracking Reflection Tracking Directivity	5 Hz to 110 GHz	0.05 dB 0.02 dB 1.5 dB	Agilent/HP 85052D, 85056A, PSNA TRL calibration kit
Noise Figure Meter/Analyzer <sup>3</sup> –			
Noise Figure Ranging	(0 to 30) dB	0.09 dB	Agilent/HP 346A/B/C, 346C opt K01
Noise Figure Gain Ranging	(-20 to +40) dB	0.09 dB	Agilent/HP 346A/B/C, 346C opt K01, Avantek amplifier
Time Base	(1, 5, 10) MHz	5 x 10 <sup>-13</sup>	NIST FMAS, NIST TMAS, Agilent 83650B
Frequency Accuracy	10 MHz to 110 GHz	3 ppm	NIST FMAS, NIST TMAS, Agilent 83650B
Noise Figure	10 MHz to 110 GHz	0.12 dB	Agilent/HP 346A/B/C, 346C opt K01, C.P. Clare TN-172, C.P. Clare TN-164, C.P. Clare TN-165
Reflection Coefficient	10 MHz to 110 GHz	±0.04 Γ	Agilent/HP 8753ES, 8510C, 8517B, V85104A, W85104A

Parameter/Equipment	Range	CMC <sup>2, 4, 8</sup> ( $\pm$ )	Comments
Oscilloscope Calibration <sup>3</sup> –			
Rise/ Fall Time	(10 to 90) %	1.6 ps	Wavetek 9550 pulse head
Square Wave 50 $\Omega$ or 1 M $\Omega$ load impedance –			
< 10 kHz	(40 $\mu$ V <sub>pp</sub> to 1 mV) $\mu$ V <sub>pp</sub> 1 mV to 5 V <sub>pp</sub>	2.5 % 0.13 %	Wavetek 9500B-3200
Horizontal/Cursor Accuracy	180.19 ps to 55.00 s	0.4 parts in 10 <sup>6</sup>	Wavetek 9500B-3200
Vertical/Cursor Accuracy	$\pm$ (1 mV to 200 V)	0.05 %	Wavetek 9500B-3200, Agilent/HP 3458A
Bandwidth	100 MHz to 300 MHz (300 to 500) MHz 550 MHz to 3 GHz (3 to 6) GHz (6 to 26.5) GHz (26.5 to 50) GHz (50 to 75) GHz (75 to 110) GHz	2.4 % 3.0 % 4.1 % 5.8 % 4.2 % 7.0 % 7.7 % 7.7 %	Wavetek 9500B-3200, Wavetek 9560 Agilent/HP 8485A, 8487A, V8486A, W8486A
Power Divider/Splitter <sup>3</sup> –			
Insertion Loss	5 Hz to 67 GHz (67 to 110) GHz	0.08 dB 0.20 dB	Agilent/HP E8361A, 8510C, 8517B V85104A, W85104A
Insertion Phase	5 Hz to 67 GHz (67 to 110) GHz	0.6° 5.0°	
Reflection Coefficient	5 Hz to 67 GHz (67 to 110) GHz	0.03 $\Gamma$ 0.03 $\Gamma$	
Insertion Loss Tracking	5 Hz to 67 GHz (67 to 110) GHz	0.10 dB 0.30 dB	
Phase Tracking	5 Hz to 110 GHz (67 to 110) GHz	0.8° 6.5°	

Parameter/Equipment	Range	CMC <sup>2, 8</sup> (±)	Comments
Power Meter <sup>3</sup> –			
Range	(20 to -35) dBm (<-35 to -60) dBm	0.05 dB 0.10 dB	Boonton 2520, Agilent/HP 11683A,
Reference Source	1000 mW @ 50 MHz	0.35 %	PSNA reference source
Reference Source Linearity	(20 to -30) dBm (<-30 to -60) dBm	0.01 dB 0.03 dB	Agilent/HP 8902, N5531S, 355C/D
Power – Measure RF/mW Absolute <sup>3</sup>			
Type N	(0.1 to 100) MHz (0.1 to 14) GHz (14 to 18) GHz	0.3 % 0.4 % 0.5 %	Rohde & Schwarz NRV5/NRV-5, NIST CN mount
3.5 mm	(0.05 to 18) GHz (18 to 33) GHz	1.0 % 1.3 %	Hughes/Agilent/HP thermistor mounts with Cx adapter
2.92 mm	(0.05 to 1) GHz (1 to 10) GHz (10 to 20) GHz (20 to 25) GHz (25 to 40) GHz	0.4 % 1.1 % 1.6 % 1.7 % 2.2 %	Agilent/HP 8487A with K Cx adapter
2.4 mm	(0.05 to 0.5) GHz (1 to 8) GHz (8 to 18) GHz (18 to 26.5) GHz (26.5 to 40) GHz (40 to 50) GHz	0.5 % 1.3 % 1.6 % 1.6 % 1.6 % 1.6 %	Hughes/Agilent/HP thermistor mounts with Cx adapter, Agilent/HP 8487A, 8487D
WR-42	(18 to 26.5) GHz	1.1 %	Hughes/Millitech/Agilent/HP thermistor mounts
WR-28	(26.5 to 40) GHz	1.1 %	
WR-22	(33 to 50) GHz	1.5 %	
WR-15	(50 to 75) GHz	2.0 %	
WR-10	(75 to 110) GHz	2.5 %	

Parameter/Equipment	Range	CMC <sup>2,8</sup> (±)	Comments
Power Sensor (50 Ω)/ Thermistor Mount Characterization <sup>3</sup>			
Coaxial –			
9 kHz to 26.5 GHz	(9 to 100) kHz	0.6 %	Agilent/HP 3458A, 8510C, 8517B, E4419B, 432A, 478A opt H63, 8487B, P486A, R486A, V85104A, W85104A, Tegam 1804 NIST CN Mount, Weinschel 1109, 1119, Millitech THM-22-RF000; THM- 15-RF000, Fluke 5720A
	(0.0001 to ≤0.0003) GHz	0.4 %	
	(>0.0003 to ≤10) GHz	0.4 %	
	(>10 to >18) GHz	0.6 %	
	(>19 to ≤26) GHz	1.4 %	
	26.5 GHz	1.5 %	
(26.5 to 40) GHz	26.5 GHz	1.3 %	
	(>26.5 to ≤40) GHz	1.5 %	
(33 to 50) GHz	(33 to ≤50) GHz	2.0 %	
(50 to 65) GHz	(50 to ≤56) GHz	2.5 %	
	(>56 to ≤65) GHz	2.7 %	
Waveguide			
S Band	(2.6 to ≤3.95) GHz	1.2 %	
G Band	(3.95 to ≤5.85) GHz	1.2 %	
H Band	(7.05 to ≤10.00) GHz	1.2 %	
X Band	(8.2 to ≤12.4) GHz	1.3 %	
Ku Band	(12.4 to ≤18) GHz	1.3 %	
K Band	(18 to ≤26.5) GHz	1.3 %	
Ka Band	(26.5 to ≤40) GHz	1.5 %	
Q Band	(33 to ≤50) GHz	2.0 %	
V Band	(50 to ≤52) GHz	2.5 %	
	(>52 to ≤56) GHz	2.4 %	
	(>56 to ≤64) GHz	2.7 %	
	(>65 to ≤75) GHz	2.0 %	

Parameter/Equipment	Range	CMC <sup>2,8</sup> (±)	Comments
Power Sensor (50 Ω)/ Thermistor Mount Characterization <sup>3</sup> (cont)			
W Band	(>75 to ≤76) GHz (>76 to ≤77) GHz (>77 to ≤80) GHz (>80 to ≤81) GHz (>81 to ≤110) GHz	4.0 % 3.6 % 3.3 % 4.6 % 3.2 %	Agilent/HP 3458A, 8510C, E4419B, 432A, 478A opt H63, V85104A, W85104A, Weinschel 1109, Hughes WR-10 thermistor mount
Power Sensor Characterization (75Ω)	100 kHz to 2 GHz (>2 to 4.2) GHz	1.3 % 1.5 %	Tegam F1119, Tegam 1804, NIST CN Mount Agilent/HP 11852B
Phase Noise <sup>3</sup> –			
Measure	1 MHz to 18 GHz	2.3 dBc 1 Hz to 100 kHz Offset	HP 3048A system w/8662A and 11729C, Symmetricom 5120A opt 1
	10 MHz to 26.5 GHz	2.4 dBc 1 kHz to 1 MHz Offset	Agilent E5052A/E5053A signal source analyzer
Generate	10 MHz	1.5 dBc 1 Hz to 100 kHz Offset	Datum 8040A Oscillator
	9.75 GHz	2.4 dBc 10 Hz Offset	Techtrol-Cyclonetic Model MX 415 oscillator
		1.3 dBc 20 Hz to 2 MHz Offset	

Parameter/Equipment	Range	CMC <sup>2,4</sup> (±)	Comments
Scalar Detector <sup>3</sup> –			
Reflections	10 MHz to 26.5 GHz (26.5 to 110) GHz	0.03 $\Gamma$ 0.05 $\Gamma$	HP 8563E, Hughes/Agilent/HP thermistor mounts with Cx adapter, Agilent/HP 8487A, V8486A, W8486A, 8540C
Frequency Response	10 MHz to 40 GHz (40 to 75) GHz (75 to 110) GHz	0.15 dB 0.30 dB 0.30 dB	
Amplitude Accuracy	10 MHz to 40 GHz (40 to 75) GHz (75 to 110) GHz	0.10 dB 0.20 dB 0.20 dB	
Dynamic Accuracy	(20 to 10) dBm 0 dBm (-10 to -55) dBm	0.11 dB 0.10 dB 0.25 dB	
Spectrum Analyzers <sup>3</sup> –			
Residual Response	9 kHz to 50 GHz	0.5 dB	Agilent/HP 53132A, 8565E, 83650, Datum 4310A
Display Avg Noise	9 kHz to 50 GHz	1.3 dB	
Time Base Accuracy	10 MHz	9 x 10 <sup>-13</sup>	
Spurious Response	9 kHz to 50 GHz	1 dB	Agilent/HP 83650, 3335A, 355C/D, 438A, 8482A, 8485A, 8487A, 5335A, 53132A, 8665B
Third Order Intermodulation Distortion	100 kHz to 5 GHz	1 dB	
Second Harmonic Distortion	100 kHz to 5 GHz	0.5 dB	
Resolution Bandwidth			
Display Scale Fidelity			
(50 $\Omega$ ref to 100 kHz)	(0 to 88) dB	0.05 dB	
(75 $\Omega$ ref to 100 kHz)	(0 to 18) dB (20 to 58) dB (60 to 98) dB	0.07 dB 0.12 dB 0.24 dB	

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Spectrum Analyzers <sup>3</sup> – (cont)			
Amplitude Accuracy and Frequency Response			Agilent/HP 83650, 3335A, 355C/D, 438A, 8482A, 8485A, 8487A, 5335A, 53132A, 8665B
50 Ω	1 mHz to 200 Hz 200 Hz to 100 kHz 100 kHz to 18 GHz (18 to 50) GHz (50 to 75) GHz (75 to 110) GHz	0.12 dB 0.08 dB 0.06 dB 0.17 dB 0.20 dB 0.25 dB	
75 Ω	200 Hz to 1 kHz 1 kHz to 25 MHz (25 to 80) MHz	0.18 dB 0.09 dB 0.18 dB	
Sweep Time	0.1 μs to 100 s	2.3 μs/s	Agilent/HP 83650, 3335A, 355C/D, 438A, 8482A, 8485A, 8487A, 5335A, 53132A, 8665B
Span	1 Hz to 2 GHz	4 μHz/Hz	
Input Attenuator	50 MHz	0.08 dB	
Noise Sidebands	100 kHz to 6 GHz	0.8 dB	
Scattering Parameters <sup>3</sup> – Reflection: S <sub>11</sub> and S <sub>22</sub> Reflection Coefficient 0 to 1			
Coaxial (50/75) Ω	(0.005 to <30) kHz  (0.03 to 45) MHz  (0.045 to 0.3) GHz  (0.3 to 17) GHz	0.001 (lin) 0.1°  0.002 (lin) 0.1°  0.002 (lin) 0.1°  0.004 (lin) 0.2°	Agilent/HP3577A, 87512A, 8753ES, 8510C, 8517B, E8361A, 85052C, 85054B, 85056A, 85036B, 85038B, 85039B

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Scattering Parameters <sup>3</sup> – Reflection: S <sub>11</sub> and S <sub>22</sub> Reflection Coefficient 0 to 1  Coaxial (50/75) Ω          Waveguide Reflection: S <sub>11</sub> and S <sub>22</sub> Reflection Coefficient 0 to 1	(17 to 18) GHz	0.005 (lin) 0.3°	Agilent/HP3577A, 87512A, 8753ES, 8510C, 8517B, E8361A, 85052C, 85054B, 85056A, 85036B, 85038B, 85039B
	(18 to 40) GHz	0.015 (lin) 0.8°	
	(41 to 50) GHz	0.018 (lin) 1.1°	
	(50 to 67) GHz	0.23 (lin) 1.3°	
	(2.6 to 12.4) GHz	0.009 (lin) 0.5°	Agilent/HP 8510C, 8517B, E8361A, V85104A, W85104A. PSNA TRL calibration kit, Oleson V05 VNA1- T/R
	(12.4 to 26.5) GHz	0.010 (lin) 0.5°	
	(26.5 to 50.00) GHz	0.006 (lin) 0.3°	
	(50 to 75) GHz	0.018 (lin) 1.1°	
	(75 to 110) GHz	0.024 (lin) 1.4°	
	(140 to 220) GHz	0.048 (lin) 10°	

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Scattering Parameters <sup>3</sup> – Transmission: S <sub>21</sub> and S <sub>12</sub>			
Coaxial – (50/75) Ω			
(0.005 to <30) kHz	(0 to 70) dB	0.01 dB 0.2°	Agilent/HP 3577A, 87512A, 8753ES, 8510C, 8517B, 85052C, 85054B, 85056A, 85036B, 85038B, 85039B, E8361A, 85058E
(0.03 to 45) MHz	(0 to 70) dB	0.01 dB 0.02°	
(0.045 to 67) GHz	(0 to 10) dB	0.01 dB 0.2°	
	(10 to 20) dB	0.02 dB 0.2°	
	(20 to 30) dB	0.03 dB 0.21°	
	(30 to 50) dB	0.10 dB 0.57°	
	(50 to 70) dB	0.19 dB 1.3°	
Waveguide			
(2.6 to 12.4) GHz	(0 to 30) dB	0.02 dB 0.6°	Agilent/HP 8510C, 8517B, E8361A, V85104A, W85104A, PSNA TRL calibration kit, Oleson V05 VNA1- T/R
	(30 to 50) dB	0.06 dB 0.7°	
(12.4 to 18) GHz	(0 to 30) dB	0.02 dB 0.7°	
	(30 to 50) dB	0.06 dB 0.7°	
(18 to 26.5) GHz	(0 to 30) dB	0.02 dB 0.7°	
	(30 to 50) dB	0.05 dB 0.8°	

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments	
Scattering Parameters <sup>3</sup> – Transmission: S <sub>21</sub> and S <sub>12</sub> (cont)				
Waveguide				
(26.5 to 40) GHz	(0 to 30) dB	0.03 dB 0.7	Agilent/HP 8510C, 8517B, E8361A, V85104A, W85104A, PSNA TRL calibration kit, Oleson V05 VNA1- T/R	
	(30 to 50) dB	0.06 dB 1.4°		
(40.0 to 50.0) GHz	(0 to 30) dB	0.03 dB 1.0°		
	(30 to 50) dB	0.09 dB 2.1°		
(50 to 75.0) GHz	(0 to 30) dB	0.05 dB 3.3°		
	(30 to 50) dB	0.01 dB 3.4°		
(75 to 110) GHz	(0 to 30) dB	0.06 dB 4.6°		
	(30 to 50) dB	0.11 dB 5.4°		
(140 to 220) GHz	(0 to 30) dB	0.7 dB 9.3°		
	(30 to 40) dB	1.0 dB 14°		
Scattering Parameters <sup>3</sup> – Electrical/Group Delay	30 kHz to 45 MHz 45 MHz to 67 GHz (67 to 110) GHz	230 ps 21 ps 350 ps		Agilent/HP 8510C, 8517B, V85104A, W85104A, 85052C, 85054B, 85056A, 8503B, 85038B, 85039B, E8361A, 85058E, PSNA TRL calibration kit, Oleson V05 VNA1-T/R

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Thermal Noise <sup>3</sup> –			
Coaxial			
(0.01 to 50) GHz	(≥0.01 to <1.0) GHz	0.08 dB	Agilent/HP 8970B, 8971C, N8975A, 346A, 346B, 346C, 346C opt K01, 8510C, 8517B, Clare TN162 (WR-28), TN 172 (WR-22),
(5 to 30) dB ENR	(≥1.0 to ≤11) GHz	0.09 dB	
	(>11 to ≤18) GHz	0.13 dB	
	(>18 to ≤26.5) GHz	0.12 dB	
	(>26.5 to ≤35) GHz	0.13 dB	
	(>35 to ≤50) GHz	0.16 dB	
Waveguide –			
(26.5 to 50) GHz	(26.5 to ≤27) GHz	0.07 dB	Agilent/HP 8970B, 8971C, N8975A, 346C opt K01, 8510C, 8517B, Clare TN162 (WR-28), TN 172 (WR-22), TN164 (WR-15), TN 165 (WR-10)
(5 to 30) dB ENR	(>27 to ≤31) GHz	0.06 dB	
	(>31 to ≤39) GHz	0.08 dB	
	40 GHz	0.10 dB	
	(>40 to ≤50) GHz	0.13 dB	
(50 to 75) GHz	(50 to ≤54) GHz	0.15 dB	Agilent/HP 8970B, 8971C, N8975A, 346C opt K01, 8510C, Clare TN162 (WR-28), TN 172 (WR-22), TN164 (WR-15), TN 165 (WR- 10)
(5 to 30) dB ENR	55 GHz	0.11 dB	
	(>55 to ≤63) GHz	0.16 dB	
	(>63 to ≤65) GHz	0.09 dB	
	66 GHz	0.17 dB	
	67 GHz	0.19 dB	
	68 GHz	0.21 dB	
	69 GHz	0.24 dB	
	70 GHz	0.25 dB	
	71 GHz	0.27 dB	
	72 GHz	0.29 dB	
	73 GHz	0.32 dB	
	74 GHz	0.34 dB	
	75 GHz	0.36 dB	

Parameter/Equipment	Range	CMC <sup>2, 8</sup> (±)	Comments
Thermal Noise <sup>3, 10</sup> – (cont)  Waveguide –  (75 to 110) GHz (5 to 30) dB ENR	(75 to ≤77) GHz (>77 to ≤80) GHz (>80 to ≤89) GHz (>89 to <94) GHz (>94 to ≤100) GHz 101 GHz 102 GHz 103 GHz 104 GHz 105 GHz 106 GHz 107 GHz 108 GHz 109 GHz 110 GHz	0.30 dB 0.31 dB 0.44 dB 0.35 dB 0.43 dB 0.78 dB 0.77 dB 0.77 dB 0.76 dB 0.75 dB 0.94 dB 1.1 dB 1.3 dB 1.5 dB 1.7 dB	Agilent/HP 8970B, N8975A, Clare TN164 (WR-15), TN165 (WR-10)
Tuned RF Level <sup>3</sup> –  (0 to 10) dB (0 to 20) dB (0 to 30) dB (0 to 40) dB (0 to 50) dB (0 to 60) dB (0 to 70) dB (0 to 80) dB (0 to 90) dB (0 to 100) dB (0 to 110) dB (0 to 120) dB	2 MHz to 110 GHz	0.015 dB 0.015 dB 0.015 dB 0.015 dB 0.015 dB 0.015 dB 0.015 dB 0.015 dB 0.015 dB 0.015 dB 0.020 dB 0.060 dB 0.19 dB	Agilent/HP 8902A measuring receiver with Agilent/HP 11793A microwave converter or 11970 series harmonic mixer or Oleson microwave lab mixers Agilent/HP N5531S
Watt Meter	450 kHz to 2.7 GHz	1.5 %	Agilent/HP E4418A, 8482A, Amplifier Research DC3002

IV. Fluid Quantities

Parameter/Equipment	Range	CMC <sup>2,8</sup> (±)	Comments
Gas Flow	10 sccm to 30 slpm (30 to 100) slpm	0.5 % 0.7 %	Nitrogen, air, argon, mass flow standards
Gas Flow <sup>3</sup>	(10 to 200) sccm (0.20 to 20) slpm	3.0 % 0.9 %	Nitrogen, air, argon, mass flow standards
Helium Leak Rate	(10 <sup>-09</sup> to 10 <sup>-03</sup> ) sccs	10 %	Standard comparison

V. Mechanical

Parameter/Equipment	Range	CMC <sup>2,8</sup> (±)	Comments
Accelerometer – 0.1 mV to 10 V/g or pc/g	Sinusoidal (2 to 4) Hz 5 Hz to 2 kHz (2 to 10) kHz  Shock (20 to 10 000) g	2.5 % 1.5 % 2.5 %  2.0 %	Bouche vibration system; Endevco 2270M8 standard accelerometer (reference & check standard)  Shock system & standard shock accelerometer
Force	(15 to 330) lbf (300 to 1000) lbf (1000 to 2000) lbf (2000 to 5000) lbf (5000 to 10 000) lbf (10 000 to 25 000) lbf (25 000 to 50 000) lbf (50 000 to 100 000) lbf	0.045 % 0.6 lbf 1 lbf 2.4 lbf 3.7 lbf 8.7 lbf 22 lbf 220 lbf	Dead weight, proving ring, load cell

Parameter/Equipment	Range	CMC <sup>2, 8</sup> (±)	Comments		
Scales and Balances <sup>3</sup>	(5 to 500) mg	0.012 mg	Class 1 masses		
	(0.5 to 5) g	0.044 mg			
	(5 to 10) g	0.064 mg			
	(10 to 20) g	0.093 mg			
	(20 to 50) g	0.14 mg			
	(50 to 100) g	0.30 mg			
	(100 to 200) g	0.59 mg			
	(200 to 500) g	1.5 mg			
	(500 to 1000) g	3.2 mg			
	(1 to 2) kg	13 mg			
	(2 to 5) kg	19 mg			
	(5 to 20) kg	100 mg			
	(50 to 2000) lb	0.025 %		Class F masses	
	(2000 to 5000) lb	0.080 %			
Pressure	(0.2 to 100) psia/psig	0.0036 %	Ruska 2465		
	(100 to 1000) psia/psig	0.0040 %	Ruska 2475/2485		
	(1000 to 15 000) psig	0.0044 %			
Pressure <sup>3</sup>	(5 to 500) psig	0.16 psi	Heise PTE-1 w/ an HQS module		
	(500 to 2000) psig	1.2 psi			
	(2000 to 6000) psig	1.8 psi			
	(6000 to 10 000) psig	12 psi			
Vacuum –  Ionization Gauge	2.0 x 10 <sup>-07</sup> torr	8.4 %	Ionization gauge		
	5.0 x 10 <sup>-07</sup> torr	5.0 %			
	9.0 x 10 <sup>-07</sup> torr	4.4 %			
	2.0 x 10 <sup>-06</sup> torr	6.5 %	Spinning rotor gauge		
	5.0 x 10 <sup>-06</sup> torr	4.4 %			
	9.0 x 10 <sup>-06</sup> torr	3.0 %			
	2.0 x 10 <sup>-05</sup> torr	6.3 %			
	5.0 x 10 <sup>-05</sup> torr	3.4 %			
	9.0 x 10 <sup>-05</sup> torr	2.9 %			
	2.0 x 10 <sup>-04</sup> torr	6.6 %			
	5.0 x 10 <sup>-04</sup> torr	3.6 %			
	9.0 x 10 <sup>-04</sup> torr	2.9 %			
	Thermocouple Vacuum Gauge/Capacitance Manometer	(0.01 to 0.1) torr		0.6 % + 0.3 mtorr	Capacitance diaphragm gauge Ruska 2465
		(0.1 to 10) torr		0.6 % + 2 mtorr	
(10 to 1000) torr		0.0066 %			

Parameter/Equipment	Range	CMC <sup>2,8</sup> (±)	Comments
Mass	(2 to 5) kg (1 to 2) kg (0.5 to 1) kg (200 to 500) g (100 to 200) g (50 to 100) g (20 to 50) g (10 to 20) g (5 to 10) g (2 to 5) g (1 to 2) g (0.5 to 1) g (1 to 500) mg  (20 to 50) lb (10 to 20) lb (5 to 10) lb	33 mg 26 mg 5.2 mg 2.3 mg 0.91 mg 0.46 mg 0.23 mg 0.12 mg 0.075 mg 0.043 mg 0.040 mg 0.040 mg 0.012 mg  0.00059 lb 0.00055 lb 0.000063 lb	Class 1 masses and electronic balances
Torque Transducers	(20 to 320) in-oz (9 to 100) in-lb (10 to 100) ft-lb (100 to 1000) ft-lb	0.03 % 0.03 % 0.03 % 0.03 %	Standard weights, torque moment arms
Torque Wrench and Torque Screwdriver	(20 to 320) in-oz (9 to 100) in-lb (10 to 100) ft-lb (100 to 1000) ft-lb	0.7 % 0.7 % 0.7 % 0.7 %	AKO TSD6000

## VI. Optical Quantities

Parameter/Equipment	Range	CMC <sup>2,8</sup> (±)	Comments
Fiber Optic Power – (Single Mode) 1310 nm 1550 nm  (Multi Mode) 850 nm 1300 nm	  (-60 to 5) dBm (-60 to 5) dBm  (-60 to -10) dBm (-60 to -10) dBm	  1.1 % 1.1 %  1.1 % 1.1 %	  EXFO 1502

Parameter/Equipment	Range	CMC <sup>2,8</sup> (±)	Comments
Fiber Optic Attenuation – (Single Mode) 1310 nm 1550 nm  (Multi Mode) 850 nm 1300 nm	(0 to 60) dB (0 to 60) dB  (0 to 60) dB (0 to 60) dB	0.5 % 0.5 %  0.5 % 0.5 %	EXFO 1502
Fiber Optic Wavelength –  Wavelength Meter  Measure (Single Mode)  (Multi Mode)	(1528 to 1563) nm   (700 to 1700) nm  (550 to 2000) nm	0.0014 nm   0.0021 nm  3 nm	NIST SRM 2519  Burleigh WA-1650  Newport 77250
Fiber Optic Optical Time Domain Reflectometer, Fixed Points –  (Single Mode) 1310, 1550 nm	2.3 km 13.1 km	2 m 3 m	NPL optical length reference
Laser Power, Fixed Points –  1.06 μm	2 W	1.7 %	Calorimeter
Laser Energy  1.06 μm	100 μJ to 150 mJ	3.8 %	Calorimeter

Parameter/Equipment	Range	CMC <sup>2, 8</sup> (±)	Comments
Optical Pyrometer	800 °C to 849 °C 850 °C to 949 °C 950 °C to 1049 °C 1050 °C to 1149 °C 1150 °C to 1249 °C 1250 °C to 1349 °C 1350 °C to 1449 °C 1450 °C to 1549 °C 1550 °C to 1649 °C 1650 °C to 1749 °C 1750 °C to 1849 °C 1850 °C to 1949 °C 1950 °C to 2049 °C 2050 °C to 2149 °C 2150 °C to 2249 °C 2250 °C to 2300 °C	2.5 °C 2.4 °C 2.2 °C 2.2 °C 2.2 °C 2.1 °C 2.5 °C 2.5 °C 2.5 °C 2.5 °C 2.6 °C 3.0 °C 3.0 °C 3.0 °C 3.1 °C 3.1 °C	NIST tungsten strip lamp
Luminous Intensity	(20 to 500) fc	0.8 %	NIST luminous intensity lamp

## VII. Thermodynamics

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Resistance Thermometry, Fixed Points	-195.5 °C -38.8344 °C 0.0100 °C 231.9280 °C 419.527 °C	2.3 mK 1.4 mK 0.4 mK 2.5 mK 2.8 mK	DCC resistance bridge, standard resistors, TPW Cell, NIST SPRT, LN <sub>2</sub> comparator, TP mercury cell, FP Tin cell, FP Zinc cell
Temperature – Measuring Equipment & Measure <sup>3</sup>  Fixed Points	-195.5 °C 0.01 °C (TPW)	0.006 °C 0.0004 °C	Super thermometer, SPRT, TPW cell, Oil Bath, LN <sub>2</sub> nanovoltmeter, Type S thermocouple, furnace

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Temperature – Measuring Equipment & Measure <sup>3</sup> (cont)	(-80 to 0) °C (1 to 125) °C (126 to 300) °C (301 to 660) °C (661 to 1000) °C	0.004 °C 0.002 °C 0.004 °C 0.1 °C 0.16 °C	Super thermometer, SPRT, TPW cell, Oil Bath, LN <sub>2</sub> nanovoltmeter, Type S thermocouple, furnace
Relative Humidity Indicators <sup>3</sup>	(20 to 85) % RH	0.9 % RH	Thunder Scientific 2500ST humidity chamber
Dewpoint/Frostpoint Indicators	(-80 to 10) °C	0.35 °C	Thunder Scientific 3900 low humidity generator

#### VIII. Time & Frequency

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Frequency – Measure Frequency Offset Frequency Stability	(1, 5, 10) MHz (1, 5, 10) MHz	5.8 parts in 10 <sup>-14</sup> 5.8 parts in 10 <sup>-14</sup>	Datum 4310 cesium standard, NIST frequency measurement and analysis system (FMAS), NIST Time Measurement and Analysis System (TMAS)
Allan Variance	(1, 5, 10) MHz	7.8 x 10 <sup>-14</sup>	HP 5370B, Symmetricom 5120A Opt 01 Phase Noise and Allan deviation test set.
Stop Watches – Timers	With Human Interaction Without Human Interaction	0.6 s 0.23 s	HP 5326, cesium standard NIST frequency measurement and analysis system (FMAS)

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- <sup>1</sup> This laboratory offers commercial calibration service and field calibration service.
- <sup>2</sup> Calibration and Measurement Capability (CMC) is the smallest uncertainty of measurement that a laboratory can achieve within its scope of accreditation when performing more or less routine calibrations of nearly ideal measurement standards or nearly ideal measuring equipment. Calibration and Measurement Capabilities represent expanded uncertainties expressed at approximately the 95 % level of confidence, usually using a coverage factor of  $k = 2$ . The actual measurement uncertainty of a specific calibration performed by the laboratory may be greater than the CMC due to the behavior of the customer's device and to influences from the circumstances of the specific calibration.
- <sup>3</sup> Field calibration service is available for this calibration and this laboratory meets A2LA R104 – *General Requirements: Accreditation of Field Testing and Field Calibration Laboratories* for these calibrations. Please note the actual measurement uncertainties achievable on a customer's site can normally be expected to be larger than the CMC found on the A2LA Scope. Allowance must be made for aspects such as the environment at the place of calibration and for other possible adverse effects such as those caused by transportation of the calibration equipment. The usual allowance for the actual uncertainty introduced by the item being calibrated, (e.g. resolution) must also be considered and this, on its own, could result in the actual measurement uncertainty achievable on a customer's site being larger than the CMC.
- <sup>4</sup> In the statement of CMC,  $L$  is the numerical value of the nominal length of the device measured in inches or millimeters.  $\Gamma$  refers to the magnitude of the reflection value being read.
- <sup>5</sup> “Infinity” refers to an optical focus at infinity for light collimation
- <sup>6</sup> The measurands stated are generated with the Fluke 5700 series of instruments. This capability is suitable for the calibration of the devices intended to measure the stated measurand in the ranges indicated. Calibration and Measurement Capability (CMC) are expressed as either a specific value that covers the full range or as a fraction of the reading plus a fixed floor specification.
- <sup>7</sup> The measurands stated are measured with the HP 3458A. This capability is suitable for the calibration of the devices intended to generate the measurand in the ranges indicated. Calibration and Measurement Capability (CMC) are expressed as either a specific value that covers the full range or as a combination of the fraction of the reading/output plus a range specification.
- <sup>8</sup> In the statement of CMC, percentages are to be read as percent of reading, unless noted otherwise.
- <sup>9</sup> Estimated Calibration and Measurement Capability (CMC) are derived using the “NIST 18 Term Error Analysis” technique.
- <sup>10</sup> Above 100 GHz and up to 110 GHz, noise reference standard's ENR are derived empirically.



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*EL Segundo, CA*

for technical competence in the field of

### Calibration

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005 *General Requirements for the Competence of Testing and Calibration Laboratories*. This laboratory also meets the requirements of ANSI/NCSLI Z540-1-1994 and the requirements of ANSI/NCSLI Z540.3-2006 and any additional program requirements in the field of calibration. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communiqué dated 8 January 2009).



Presented this 4<sup>th</sup> day of October 2011.

A handwritten signature in black ink, appearing to read "Peter M. Meyer", written over a horizontal line.

President & CEO  
For the Accreditation Council  
Certificate Number 1964.01  
Valid to October 31, 2013

*For the calibrations to which this accreditation applies, please refer to the laboratory's Calibration Scope of Accreditation.*