



World Class Accreditation

The American Association for Laboratory Accreditation

Accredited Laboratory

A2LA has accredited

PRIMARY STANDARDS NORTH AMERICA, INC.

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/NCSL Z540-1-1994 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 29th day of October 2009.





Peter Meyer

President & CEO
For the Accreditation Council
Certificate Number 1964.01
Valid to October 31, 2011

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



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

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CALIBRATION

Valid To: October 31, 2011

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 calibrations¹:

I. Dimensional

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Gage blocks	(0.01 to 4) in	(2 + L) μin	Electromechanical comparison
Cylindrical Ring Gages	(0 to 4) in	(6 + 12L) μin	Gage blocks, internal comparison
Cylindrical Plug Gages	(0 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 ^{2, 4, 8} (±)	Comments
Micrometers –			
Outside	(0 to 12) in	(35 + 6L) μin	Gage blocks
Depth	(0 to 12) in	(40 + 6L) μin	
Inside	(0 to 12) in	(30 + 6L) μin	
Calipers	(0 to 60) in	(380 + 5L) μin	Gage blocks, ring gage
Height Gages	(0 to 24) in	(380 + 5L) μin	Gage blocks
Dial/Digital Indicators	(0 to 0.2) in (0 to 1) in	20 μin 40 μin	Gage blocks
Surface Plate ³	(60 x 96) in	$12\sqrt{L}$ μin	Electronic level
Connector Gage Masters	(0 to 0.25) in (0 to 50) μin	220 μin 16 μin	Dial Indicator, optical flat
Torque Moment Arms	(0 to 24) in	(250 + 50L) μin	Gage blocks, dial indicator
Length Measurement	(0 to 12) in (12 to 60) in	(10 + 10L) μin (150 + 12L) μin	Laser interferometer
Angle –			
Autocollimators	(0 to 1000) arc s	(0.3 % + 0.4) arc s	Laser interferometer
Angle Generator	(0 to 1000) arc s	(0.25 %) arc s	
Electronic Level	(0 to 200) arc s (0 to 1000) arc s	1.5 arc s 3.0 arc s	
Optical Wedge	(0 to 30) arc s	1 arc s	Autocollimator
Alignment Collimator ⁵	2 ft to Infinity	2 arc s	Optical wedge

Parameter/Equipment	Range	CMC ² (±)	Comments
Theodolite/Transit/ Alignment Telescope –			
Collimation ⁵	Infinity Focus	1.2 arc s	Alignment collimator
Line of Sight ⁵	2 ft to Infinity	1.7 arc s	
Trunnion Axis	(60 to 135) °	4 arc s	

II. Electrical – DC/Low Frequency

Parameter/Equipment	Range	CMC ^{2, 4, 6, 7} (±)	Comments
DC Voltage ³ –			
Fixed Points	0.1 V 1 V 10 V 100 V 1000 V	0.77 μV/V 0.24 μV/V 0.22 μV/V 0.51 μV/V 1 μV/V	Fluke 732B HP 34420A NVM HP 3458A DMM Data proof 160 scanner Fluke 752A
	(2 to 60) kV	0.004 %	PTB voltage divider Agilent 3458A DMM Fluke 5720A calibrator
	(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	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	
Resistance – Measure ³	(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 (2 to 9) Ω (11 to 99) Ω (200 to 900) Ω	1.5 μΩ/Ω 3.4 μΩ/Ω 2.4 μΩ/Ω 1.5 μΩ/Ω 3.4 μΩ/Ω 2.4 μΩ/Ω 1.5 μΩ/Ω 1.1 μΩ/Ω 0.35 μΩ/Ω 0.52 μΩ/Ω 0.52 μΩ/Ω	Guideline 6675A, 6623; L&N standard resistors; ESI SR 1010, SR 1050; Hart 7009 oil bath; MI 9300 air bath

Parameter/Equipment	Range	CMC ^{2, 8} (±)	Comments
Resistance – Measure ³ (cont)	(2 to 9) kΩ (11 to 100) kΩ 200 kΩ to 1 MΩ (2 to 10) MΩ (11 to 100) MΩ (200 to 900) MΩ	0.55 μΩ/Ω 0.71 μΩ/Ω 1.4 μΩ/Ω 2.2 μΩ/Ω 7.2 μΩ/Ω 16 μΩ/Ω	Guideline 6675A, 6623; L&N standard resistors; ESI SR 1010, SR 1050; Hart 7009 oil bath; MI 9300 air bath
Resistance – Measure ³ Fixed Points	0.1 Ω 0.2 Ω 1 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ 1 GΩ	0.71 μΩ/Ω 0.73 μΩ/Ω 0.26 μΩ/Ω 0.26 μΩ/Ω 0.46 μΩ/Ω 0.46 μΩ/Ω 0.48 μΩ/Ω 31 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 ³ @ 1 kHz Fixed Points	(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) 1 pF 2 pF 200 pF	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 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 ³ @ 1 kHz	(2 to 4) nF (6 to 10) nF (30 to 40) nF (60 to 100) nF (300 to 400) nF (600 to 1000) nF (1 μF)	3.6 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

Parameter/Equipment	Range	CMC ² (±)	Comments
Capacitance – Measure ³ (cont)			
Fixed Points	5 nF 20 nF 50 nF 200 nF 500 nF	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	10 pF	4.4 µF/F	Standard capacitors
0.1 kHz	10 pF	1.6 µF/F	
0.4 kHz	10 pF	0.62 µF/F	
0.8 kHz	10 pF	0.54 µF/F	
1 kHz	10 pF	0.39 µF/F	
2 kHz	10 pF	0.38 µF/F	
6 kHz	10 pF	0.59 µF/F	
8 kHz	10 pF	0.97 µF/F	
10 kHz	10 pF	1.2 µF/F	
16 kHz	10 pF	2.7 µF/F	
20 kHz	10 pF	4.1 µF/F	
0.05 kHz	100 pF	1.9 µF/F	
0.1 kHz	100 pF	1.0 µF/F	
0.4 kHz	100 pF	0.58 µF/F	
0.8 kHz	100 pF	0.52 µF/F	
1 kHz	100 pF	0.37 µF/F	
2 kHz	100 pF	0.37 µF/F	
6 kHz	100 pF	0.50 µF/F	
8 kHz	100 pF	0.84 µF/F	
10 kHz	100 pF	0.97 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	

Parameter/Equipment	Range	CMC ² (±)	Comments
Electrical Calibration of Thermocouple Indicating Devices ³ –			
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 017 °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	
DC Current – Generate and Measure ³	(1 to 99) µA 100 µA to 30 mA (31 to 100) mA (101 to 300) mA (301 to 400) mA (401 to 500) mA (501 to 799) mA (800 to 900) mA 901 mA to 15 A	5 µA/A 4 µA/A 5 µA/A 6 µA/A 13 µA/A 13 µA/A 11 µA/A 9 µA/A 8 µA/A	

Parameter/Equipment	Range	CMC ^{2, 8} (±)	Comments
DC Current – Generate and Measure ³ (cont)	(16 to 50) A (51 to 70) A (71 to 100) A (101 to 400) A	15 μA/A 21 μA/A 26 μA/A 62 μA/A	Stable DC source standard resistor, voltmeter
Inductance – Generate and Measure	100 μH @ 1 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	0.008 % 0.010 % 0.008 % 0.015 % 0.008 % 0.020 % 0.009 % 0.015 % 0.024 % 0.016 % 0.015 % 0.016 % 0.016 %	HP 4274A LCR meter, GR 1482B,E,H,L,P,T standard inductors
AC Voltage Flatness – Measure 0.45 V	0.3 MHz 1 MHz 3 MHz 10 MHz 30 MHz 50 MHz 80 MHz 100 MHz	0.02 % 0.04 % 0.03 % 0.04 % 0.05 % 0.08 % 0.16 % 0.36 %	Ballantine thermal voltage converters: 1395B-0.4-09 1395B-1-09 1395B-3-09

Parameter/Equipment	Range	CMC ^{2, 8} (±)	Comments
AC Voltage Flatness – Measure (cont)			
1 V	0.3 MHz 1 MHz 3 MHz 10 MHz 30 MHz 50 MHz 80 MHz 100 MHz	0.02 % 0.04 % 0.03 % 0.04 % 0.05 % 0.08 % 0.16 % 0.30 %	Ballantine thermal voltage converters: 1395B-0.4-09 1395B-1-09 1395B-3-09
3 V	0.3 MHz 1 MHz 3 MHz 10 MHz 30 MHz 50 MHz 80 MHz 100 MHz	0.02 % 0.04 % 0.03 % 0.04 % 0.05 % 0.08 % 0.16 % 0.24 %	
AC Voltage – Generate and Measure ³			
2 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	0.033 % 0.061 % 0.045 % 0.031 % 0.037 % 0.029 % 0.026 % 0.028 % 0.059 % 0.033 % 0.042 % 0.038 % 0.059 %	Fluke 792A AC/DC thermal transfer standard

Parameter/Equipment	Range	CMC ^{2, 8} (±)	Comments
AC Voltage – Generate and Measure ³ (cont)			
6 mV	10 Hz	0.014 %	Fluke 792A AC/DC thermal transfer standard
	20 Hz	0.013 %	
	40 Hz	0.016 %	
	100 Hz	0.013 %	
	1 kHz	0.016 %	
	10 kHz	0.013 %	
	20 kHz	0.013 %	
	50 kHz	0.013 %	
	100 kHz	0.016 %	
	300 kHz	0.013 %	
	500 kHz	0.018 %	
	800 kHz	0.014 %	
	1 MHz	0.022 %	
	10 mV	10 Hz	
20 Hz		0.010 %	
40 Hz		0.010 %	
100 Hz		0.011 %	
1 kHz		0.013 %	
10 kHz		86 μV/V	
20 kHz		80 μV/V	
50 kHz		71 μV/V	
100 kHz		0.010 %	
300 kHz		93 μV/V	
500 kHz		91 μV/V	
800 kHz		97 μV/V	
1 MHz		0.012 %	
20 mV		10 Hz	64 μV/V
	20 Hz	53 μV/V	
	40 Hz	49 μV/V	
	100 Hz	52 μV/V	
	1 kHz	56 μV/V	
	10 kHz	51 μV/V	
	20 kHz	53 μV/V	
	50 kHz	49 μV/V	
	100 kHz	53 μV/V	
	300 kHz	59 μV/V	
	500 kHz	59 μV/V	
	800 kHz	77 μV/V	
	1 MHz	94 μV/V	

Parameter/Equipment	Range	CMC ² (±)	Comments
AC Voltage – Generate and Measure ³ (cont)			
60 mV	10 Hz	36 μV/V	Fluke 792A AC/DC thermal transfer standard
	20 Hz	30 μV/V	
	40 Hz	29 μV/V	
	100 Hz	27 μV/V	
	1 kHz	28 μV/V	
	10 kHz	28 μV/V	
	20 kHz	27 μV/V	
	50 kHz	28 μV/V	
	100 kHz	30 μV/V	
	300 kHz	35 μV/V	
	500 kHz	37 μV/V	
	800 kHz	44 μV/V	
	1 MHz	52 μV/V	
	100 mV	10 Hz	
20 Hz		21 μV/V	
40 Hz		22 μV/V	
100 Hz		20 μV/V	
1 kHz		21 μV/V	
10 kHz		20 μV/V	
20 kHz		20 μV/V	
50 kHz		22 μV/V	
100 kHz		20 μV/V	
300 kHz		22 μV/V	
500 kHz		20 μV/V	
800 kHz		30 μV/V	
1 MHz		35 μV/V	
200 mV		10 Hz	18 μV/V
	20 Hz	16 μV/V	
	40 Hz	16 μV/V	
	100 Hz	16 μV/V	
	1 kHz	17 μV/V	
	10 kHz	16 μV/V	
	20 kHz	16 μV/V	
	50 kHz	16 μV/V	
	100 kHz	16 μV/V	
	300 kHz	17 μV/V	
	500 kHz	19 μV/V	
	800 kHz	23 μV/V	
	1 MHz	30 μV/V	

Parameter/Equipment	Range	CMC ² (±)	Comments
AC Voltage – Generate and Measure ³ (cont)			
600 mV	10 Hz	14 μV/V	Fluke 792A AC/DC thermal transfer standard
	20 Hz	13 μV/V	
	40 Hz	13 μV/V	
	100 Hz	14 μV/V	
	1 kHz	13 μV/V	
	10 kHz	13 μV/V	
	20 kHz	13 μV/V	
	50 kHz	14 μV/V	
	100 kHz	14 μV/V	
	300 kHz	15 μV/V	
	500 kHz	18 μV/V	
	800 kHz	21 μV/V	
	1 MHz	27 μV/V	
	1 V	10 Hz	
20 Hz		13 μV/V	
40 Hz		13 μV/V	
100 Hz		14 μV/V	
1 kHz		13 μV/V	
10 kHz		13 μV/V	
20 kHz		14 μV/V	
50 kHz		15 μV/V	
100 kHz		16 μV/V	
300 kHz		20 μV/V	
500 kHz		27 μV/V	
800 kHz		38 μV/V	
1 MHz		44 μV/V	
2 V		10 Hz	14 μV/V
	20 Hz	14 μV/V	
	40 Hz	14 μV/V	
	100 Hz	14 μV/V	
	1 kHz	13 μV/V	
	10 kHz	13 μV/V	
	20 kHz	14 μV/V	
	50 kHz	14 μV/V	
	100 kHz	14 μV/V	
	300 kHz	15 μV/V	
	500 kHz	19 μV/V	
	800 kHz	23 μV/V	
	1 MHz	27 μV/V	

Parameter/Equipment	Range	CMC ² (±)	Comments
AC Voltage – Generate and Measure ³ (cont)			
6 V	10 Hz	15 µV/V	Fluke 792A AC/DC thermal transfer standard
	20 Hz	13 µV/V	
	40 Hz	13 µV/V	
	100 Hz	14 µV/V	
	1 kHz	14 µV/V	
	10 kHz	14 µV/V	
	20 kHz	14 µV/V	
	50 kHz	14 µV/V	
	100 kHz	14 µV/V	
	300 kHz	15 µV/V	
	500 kHz	19 µV/V	
	800 kHz	22 µV/V	
	1 MHz	26 µV/V	
	10 V	10 Hz	
20 Hz		13 µV/V	
40 Hz		13 µV/V	
100 Hz		13 µV/V	
1 kHz		13 µV/V	
10 kHz		14 µV/V	
20 kHz		14 µV/V	
50 kHz		15 µV/V	
100 kHz		17 µV/V	
300 kHz		17 µV/V	
500 kHz		20 µV/V	
800 kHz		23 µV/V	
1 MHz		28 µV/V	
20 V		10 Hz	17 µV/V
	20 Hz	14 µV/V	
	40 Hz	13 µV/V	
	100 Hz	13 µV/V	
	1 kHz	14 µV/V	
	10 kHz	14 µV/V	
	20 kHz	14 µV/V	
	50 kHz	14 µV/V	
	100 kHz	15 µV/V	
	300 kHz	16 µV/V	
	500 kHz	19 µV/V	
	800 kHz	22 µV/V	
	1 MHz	26 µV/V	

Parameter/Equipment	Range	CMC ² (±)	Comments
AC Voltage – Generate and Measure ³ (cont)			
60 V	10 Hz	18 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	14 μV/V	
	10 kHz	15 μV/V	
	20 kHz	15 μV/V	
	50 kHz	15 μV/V	
	100 kHz	17 μV/V	
	300 kHz	18 μV/V	
100 V	10 Hz	20 μV/V	
	20 Hz	16 μV/V	
	40 Hz	15 μV/V	
	100 Hz	15 μV/V	
	1 kHz	14 μV/V	
	10 kHz	15 μV/V	
	20 kHz	15 μV/V	
	50 kHz	15 μV/V	
	100 kHz	18 μV/V	
	200 kHz	25 μV/V	
200 V	10 Hz	20 μV/V	
	20 Hz	16 μV/V	
	40 Hz	15 μV/V	
	100 Hz	15 μV/V	
	1 kHz	16 μV/V	
	10 kHz	16 μV/V	
	20 kHz	15 μV/V	
	50 kHz	15 μV/V	
	100 kHz	20 μV/V	
	600 V	10 Hz	
20 Hz		16 μV/V	
40 Hz		16 μV/V	
100 Hz		16 μV/V	
1 kHz		16 μV/V	
10 kHz		16 μV/V	
20 kHz		16 μV/V	
50 kHz		17 μV/V	
100 kHz		26 μV/V	

Parameter/Equipment	Range	CMC ^{2,7,8} (±)	Comments
AC Voltage – Generate and Measure ³ (cont)			
1000 V	10 Hz 20 Hz 40 Hz 100 Hz 1 kHz 10 kHz 20 kHz 50 kHz 100 kHz	21 μV/V 16 μV/V 16 μV/V 16 μV/V 16 μV/V 16 μV/V 20 μV/V 21 μV/V 31 μV/V	Fluke 792A AC/DC thermal transfer standard
(2 to 80) kV	60 Hz	0.25 %	PTB voltage divider; Agilent 3458A DMM
AC Current – Generate and Measure ³			
10 mA	20 Hz 400 Hz 1 kHz 5 kHz 20 kHz 50 kHz	33 μA/A 20 μA/A 20 μA/A 20 μA/A 20 μA/A 33 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	33 μA/A 20 μA/A 20 μA/A 20 μA/A	
50 mA	20 Hz 400 Hz 1 kHz 5 kHz	33 μA/A 20 μA/A 20 μA/A 20 μA/A	
100 mA	20 Hz 400 Hz 1 kHz 5 kHz 20 kHz 50 kHz	35 μA/A 23 μA/A 23 μA/A 23 μA/A 23 μA/A 47 μA/A	

Parameter/Equipment	Range	CMC ^{2,7,8} (±)	Comments
AC Current – Generate and Measure ³ (cont)			
200 mA	20 Hz 400 Hz 1 kHz 5 kHz	37 µA/A 24 µA/A 24 µA/A 24 µA/A	Holt HCS-1 AC shunts, Fluke 5720A/5725A, HP 3458A DMM, Wavetek 4920, Fluke 792A
500 mA	20 Hz 400 Hz 1 kHz 5 kHz	39 µA/A 25 µA/A 25 µA/A 25 µA/A	
1 A	20 Hz 400 Hz 1 kHz 5 kHz 20 kHz 50 kHz	41 µA/A 27 µA/A 27 µA/A 27 µA/A 27 µA/A 64 µA/A	
2 A	20 Hz 400 Hz 1 kHz 5 kHz	46 µA/A 29 µA/A 29 µA/A 29 µA/A	
5 A	20 Hz 400 Hz 1 kHz 5 kHz	61 µA/A 38 µA/A 38 µA/A 38 µA/A	
10 A	20 Hz 400 Hz 1 kHz 5 kHz 20 kHz	76 µA/A 46 µA/A 46 µA/A 46 µA/A 46 µA/A	
20 A	20 Hz 400 Hz 1 kHz 5 kHz 20 kHz	0.011 % 66 µA/A 66 µA/A 66 µA/A 66 µA/A	

Parameter/Equipment	Range	CMC ^{2,7} (±)	Comments
Ratio Transformer	400 Hz & 1 kHz	± 0.51 ppm of input	Gertsch 1011
Phase Angle – Generate @ 5 V Equal Input @ 50 mV to 100 V @ (100 to 120) V	1 Hz to 6.25 kHz (6.25 to 50) kHz (50 to 200) kHz 1 Hz to 1 kHz (1 to 6.25) kHz (6.25 to 50) kHz (50 to 200) kHz 1 Hz to 1 kHz (1 to 6.25) kHz (6.25 to 50) kHz (50 to 200) kHz	± 0.006° ± 0.012° ± 0.047° ± 0.006° ± 0.012° ± 0.018° ± 0.047° ± 0.012° ± 0.023° ± 0.035° ± 0.093°	Clark-Hess 550-2 phase standard
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	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°	Clark-Hess 6000 phase meter

Parameter/Equipment	Range	CMC ² (±)	Comments
Phase Angle – Measure (cont) @ 10 mV to 350 V	130 kHz 135 kHz 140 kHz 145 kHz 150 kHz 200 kHz 250 kHz 300 kHz 350 kHz 400 kHz 450 kHz 500 kHz	0.72° 0.74° 0.77° 0.79° 0.82° 1.07° 1.33° 1.58° 1.84° 2.09° 2.34° 2.6°	Clark-Hess 6000 phase meter

III. Electrical – RF/Microwave

Parameter/Equipment	Range	CMC ² (±)	Comments
AC Current Probe – Transfer Impedance	10 Hz to 200 MHz	1.4 dB	HP 3577A
Antenna Gain	(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	0.15 dB 0.2 dB 0.2 dB 0.25 dB 0.3 dB 0.5 dB	GP 8510C, 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 Mircrowave WR-5 gain horns
Counters ³ – 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 ⁻¹² 6.0 x 10 ⁻¹³ 0.10 dB 0.15 dB 0.20 dB 0.26 dB	 HP 5370A, Agilent 33120A, HP 83650, Agilent 83557A, Agilent 83558A, HP 8482A, HP 8385A, Agilent V8486A, Agilent W8486A

Parameter/Equipment	Range	CMC ^{2,4,8} (±)	Comments
Directional/SWR Bridge ³ – Reflections/Directivity	5 Hz to 110 GHz	0.03 Γ 1.5 dB	Agilent 8757D, Agilent 355C/D, Agilent 85054B, Agilent 8481D opt H70
Insertion Loss/Linearity	5 Hz to 67 GHz (67 to 110) GHz	0.1 dB 0.2 dB	
Directional Coupler ³ – Main Line Loss	5 Hz to 67 GHz (67 to 110) GHz	0.1 dB 0.2 dB	Agilent E8361A, HP 8510C, Agilent V85104A, Agilent W85104A
Coupling Loss	5 Hz to 67 GHz (67 to 110) GHz	0.1 dB 0.2 dB	
Reflection Directivity	5 Hz to 110 GHz 5 Hz to 110 GHz	0.03 Γ 1.5 dB	
Function/Pulse Generator ³ –			
Frequency Accuracy	1.0 μ Hz to 1 GHz	0.1 ppm	Agilent 53132A
Frequency Stability	10 MHz	9×10^{-13}	
AC Output Amplitude	1 mV to 50 V _(p-p)	105 ppm	Agilent 3458A, HP 8902
Output Flatness	DC to 100 MHz 100 MHz to 1 GHz	0.3 % 0.5 %	Balantine 1395B-1 Agilent 8482A
DC Offset	(-20 to +20) VDC	6 ppm	Agilent 3458A
Harmonic Content			
Harmonic Distortion	9 kHz to 1 GHz	1.5 dB	Agilent 8563E, HP 8903A, HP 334A, HP339A, Agilent 8903A
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, Agilent 83484A
Pulse Width/Symmetry	1 nsec to 5 sec	1.0 ns	Agilent 53132A
Phase Offset	(0 to 180) ^o	1.7 ^o	HP 3553A
AM Modulation	DC to 100 kHz	2.5 %	HP 8902, HP8903B
Gaussian Noise ³ –			
Noise Output Power	100 kHz to <18 GHz (18 to 40) GHz	1.2 % 2.6 %	Agilent 8482A/D, Agilent 8481A/D, Agilent 8485A/D, Agilent 8487 A/D

Parameter/Equipment	Range	CMC ^{2, 8} (±)	Comments
Gaussian Noise ³ – (cont)			
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 8565E
Attenuation	(0 to <10) dB (10 to <30) dB (40 to 50) dB	0.1 dB 0.2 dB 0.3 dB	Agilent 8482A/D, Agilent 8481A/D, Agilent 8485A/D, Agilent 8487A/D
Generators – Signal ³			
Attenuation			
(0 to 10) dB	100 kHz to 50 GHz	0.01 dB	HP 8902A measuring receiver with HP 11793A microwave converter or 11970 series harmonic mixer, Agilent N5531S
(0 to 20) dB		0.01 dB	
(0 to 30) dB		0.01 dB	
(0 to 40) dB		0.01 dB	
(0 to 50) dB		0.01 dB	
(0 to 60) dB		0.01 dB	
(0 to 70) dB		0.01 dB	
(0 to 80) dB		0.01 dB	
(0 to 90) dB		0.01 dB	
(0 to 100) dB		0.01 dB	
(0 to 110) dB		0.01 dB	
(0 to 120) dB		0.02 dB	
(0 to 120) dB		0.07 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 0.0151 Rad	Agilent N5531S
FM Deviation	100 kHz to 50 GHz	1.2 %	
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	

Parameter/Equipment	Range	CMC ^{2, 8} (±)	Comments		
Generators – Signal ³ (cont)					
AM Depth	(0.15 to 10) MHz	0.9 %	HP 8902, Agilent N5531S		
	10 MHz to 3 GHz	0.6 %			
	(3 to 26.5) GHz	1.8 %			
	(26.5 to 31) GHz	2.2 %			
	(31 to 50) GHz	7.0 %			
Residual AM	150 kHz to 50 GHz	0.03 %			
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	Frequency Span		HP 89441A vector signal analyzer		
GMSK, BPSK				< 100 kHz	0.6 % rms
DQPSK, n/4DQPSK				≤ 1 MHz	0.7 % rms
8 PSK, 16 QAM				> 1 MHz	1.3 % rms
QPSK, OQPSK					
Phase					
Phase Error for: MSK	Frequency Span				
GMSK, BPSK,				<100 kHz	0.6° rms
DQPSK, n/4DQPSK,				≤1 MHz	0.7° rms
8 PSK, 16 QAM & 32				>1 MHz	0.7° rms
QAM QPSK, OQPSK					
Digital Modulation – Measure					
EVM for FSK	Symbol Rate				
	3.2 kHz	1.1 % rms			
	1.152 MHz	1.8 % rms			
Harmonic Content					
Harmonics	3 Hz to 3 GHz	1.1 dB	Agilent 8565E spectrum analyzer, Agilent 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			

Parameter/Equipment	Range	CMC ² (±)	Comments
Generators – Signal ³ (cont)			
Phase Noise	1 kHz to 1 MHz offset	2.4 dB	E5052
Total Harmonic Distortion	5 Hz to 100 kHz (100 to 600) kHz	1.2 dB 2.0 dB	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	HP 8482A, HP 8481A, HP 8485A, HP 8487A, Agilent V8486A, Agilent W8486A
Time Base Aging	(5 to 10) MHz	9 x 10 ⁻¹³	Agilent 53132A
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	HP 8563E Hughes/HP thermistor mounts with Cx adapter, HP 8487A, Agilent V8486A, Agilent W8486A
Network Analyzer ³ – (Scalar/Vector)			
Time Base Accuracy	(1, 5, 10) MHz	9 x 10 ⁻¹³	HP 5370A, Agilent 3458A, Agilent 8482A, Agilent 8487A, Agilent V8487A, Agilent W8487A, Agilent 8563E
Source Absolute Accuracy	5 Hz to 110 GHz	0.04 dB	
Source Linearity/Dynamic Accuracy	5 Hz to 110 GHz	0.03 dB	
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	
Receiver Absolute Accuracy	5 Hz to 110 GHz	0.04 dB	Agilent 8482A, Agilent 8487A, Agilent V8486A, Agilent 3458A
Receiver Dynamic Accuracy & Linearity	5 Hz to 110 GHz	0.04 dB	HP 355D

Parameter/Equipment	Range	CMC ^{2,4,8} (±)	Comments
Network Analyzer ³ – (Scalar/Vector) (cont)			
Corrected Performance Transmission Tracking Reflection Tracking Directivity	5 Hz to 110 GHz	0.05 dB 0.02 dB 1.5 dB	Agilent 85052D
Noise Figure Meter/Analyzer ³ –			
Noise Figure Ranging	(0 to 30) dB	0.09 dB	Agilent 346C opt KO1
Noise Figure Gain Ranging	(-20 to +40) dB	0.09 dB	Agilent 346C opt KO1 Avantek amplifier
Time Base	(1, 5, 10) MHz	5×10^{-13}	NIST FMAS
Frequency Accuracy	10 MHz to 110 GHz	3 ppm	Agilent 83650B
Noise Figure	10 MHz to 110 GHz	0.12 dB	Agilent 346C opt KO1 C.P. Clare TN-172, C.P. Clare TN-164, C.P. Clare TN-165
Reflection Coefficient	10 MHz to 110 GHz	$\pm 0.04 \Gamma$	Agilent 87563ES
Oscilloscope Calibration ³ –			
Rise/ Fall Time	(10 to 90) %	1.6 ps	Wavetek 9550 pulse head
Square Wave 50 Ω or 1 M Ω load impedance –			
< 10 kHz	(40 μV_{pp} to 1 mV) μV_{pp} 1 mV to 5 V_{pp}	2.5 % 0.13 %	Wavetek 9500B-3200
Horizontal/Cursor Accuracy	180.19 ps to 55.00 s	0.4 ppm	
Vertical/Cursor Accuracy	$\pm(1 \text{ mV to } 200 \text{ V})$	0.05 %	Wavetek 9500B-3200, Agilent 3458A

Parameter/Equipment	Range	CMC ^{2,4,8} (±)	Comments
Oscilloscope Calibration ³ – (cont)			
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 8485A Agilent 8487A Agilent V8486A Agilent W8486A
Power Divider/Splitter ³ –			
Insertion Loss	5 Hz to 67 GHz (67 to 110) GHz	0.08 dB 0.20 dB	Agilent E8361A Agilent 8510C Agilent V85104A Agilent 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 Γ 0.03 Γ	
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°	
Power Meter ³ –			
Range	(20 to -35) dBm (<-35 to -60) dBm	0.05 dB 0.10 dB	Boonton 2520, 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	HP 8902, Agilent E4448C, Agilent 355C/D
Power – Measure RF/mW Absolute ³			
Type N	(0.1 to 100) MHz (0.1 to 14) GHz (14 to 18) GHz	0.3 % 0.4 % 0.5 %	Rohde & Schwarz NRVS/NRV-5, NIST CN mount

Parameter/Equipment	Range	CMC ^{2,8} (±)	Comments
Power – Measure RF/mW Absolute ³ (cont)			
3.5 mm	(0.05 to 18) GHz (18 to 33) GHz	1.0 % 1.3 %	Hughes/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 %	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/HP thermistor mounts with Cx adapter, HP 8487A
WR-42	(18 to 26.5) GHz	1.1 %	Hughes/Millitech/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 %	
Power Sensor (50 Ω)/ Thermistor Mount Characterization ³			HP 3456A, 432A, 8510C, 8517B 478A opt H63; Weinschel 112 Bolometer; HP 8487B, P486A, R486A; V85104A, W85104A, Millitech THM-22-RF000, THM-15-RF000, THM-10RF000 Fluke 5720A
Coaxial –			
(0.001 to 26.5) GHz	(0.00009 to <0.0001) GHz (0.0001 to ≤0.0003) GHz (>0.0003 to ≤10) GHz (>10 to >18) GHz (>19 to ≤26) GHz 26.5 GHz	0.6 % 0.4 % 0.4 % 0.6 % 1.4 % 1.5 %	
(26.5 to 40) GHz	26.5 GHz (>26.5 to ≤40) GHz	1.3 % 1.5 %	
(33 to 50) GHz	(33 to ≤50) GHz	2.0 %	
(50 to 65) GHz	(50 to ≤56) GHz (>56 to ≤65) GHz	2.5 % 2.7 %	

Parameter/Equipment	Range	CMC ^{2, 4, 8} (\pm)	Comments
Power Sensor (50 Ω)/ Thermistor Mount Characterization ³ (cont)			HP 3456A, 432A, 8510C, 8517B 478A opt H63; Weinschel 112 Bolometer; HP 8487B, P486A, R486A; V85104A, W85104A, Millitech THM-22-RF000, THM-15-RF000, THM- 10RF000 Fluke 5720A
Waveguide			
S Band	(2.6 to \leq 3.95) GHz	1.2 %	
G Band	(3.95 to \leq 5.85) GHz	1.2 %	
H Band	(7.05 to \leq 10.00) GHz	1.2 %	
X Band	(8.2 to \leq 12.4) GHz	1.3 %	
Ku Band	(12.4 to \leq 18) GHz	1.3 %	
K Band	(18 to \leq 26.5) GHz	1.3 %	
Ka Band	(26.5 to \leq 40) GHz	1.5 %	
Q Band	(33 to \leq 50) GHz	2.0 %	
V Band	(50 to \leq 52) GHz ($>$ 52 to \leq 56) GHz ($>$ 56 to \leq 64) GHz ($>$ 65 to \leq 75) GHz	2.5 % 2.4 % 2.7 % 2.0 %	
W Band	($>$ 75 to \leq 76) GHz ($>$ 76 to \leq 77) GHz ($>$ 77 to \leq 80) GHz ($>$ 80 to \leq 81) GHz ($>$ 81 to \leq 110) GHz	4.0 % 3.6 % 3.3 % 4.6 % 3.2 %	NIST CN Mount
Power Sensor Characterization (75 Ω)	100 kHz to 2 GHz ($>$ 2 to 4.2) GHz	1.3 % 1.5 %	Tegam F1119, Tegam 1805, NIST CN Mount Agilent 11852B
Phase Noise ³ – Measure	10 MHz to 18 GHz 10 MHz to 26.5 GHz	2.3 dBc 10 Hz to 100 kHz Offset 2.4 dBc 1 kHz to 1 MHz Offset	HP 3048A system w/8662A and 11729C Agilent E5052A/E5053A signal source analyzer

Parameter/Equipment	Range	CMC ^{2, 4, 8} (\pm)	Comments
Phase Noise ³ – (cont) Generate	10 MHz 9.75 GHz	1.5 dBc 1 Hz to 100 kHz Offset 2.4 dBc 10 Hz Offset 1.3 dBc 20 Hz to 2 MHz Offset	Datum 8040A Oscillator Techtrol-Cyclonetic Model MX 415 oscillator
Scalar Detector ³ – Reflections Frequency Response Amplitude Accuracy Dynamic Accuracy	10 MHz to 26.5 GHz (26.5 to 110) GHz 10 MHz to 40 GHz (40 to 75) GHz (75 to 110) GHz 10 MHz to 40 GHz (40 to 75) GHz (75 to 110) GHz (20 to 10) dBm 0 dBm (-10 to -55) dBm	0.03 Γ 0.05 Γ 0.15 dB 0.30 dB 0.30 dB 0.10 dB 0.20 dB 0.20 dB 0.11 dB 0.10 dB 0.25 dB	HP 8563E, Hughes/HP themistor mounts with Cx adapter, HP 8487A, Agilent V8486A, Agilent W8486A, Agilent 8540C
Spectrum Analyzers ³ – Residual Response Display Avg Noise Time Base Accuracy Spurious Response	9 kHz to 50 GHz 9 kHz to 50 GHz 10 MHz 9 kHz to 50 GHz	0.5 dB 1.3 dB 9×10^{-13} 1 dB	Agilent 53132A HP 83650

Parameter/Equipment	Range	CMC ² (±)	Comments
Spectrum Analyzers ³ – (cont)			
Third Order Intermodulation Distortion	100 kHz to 5 GHz	1 dB	HP 83650
Second Harmonic Distortion	100 kHz to 5 GHz	0.5 dB	
Resolution Bandwidth	1 Hz to 300 kHz	0.3 ppm	HP 3335A
Display Scale Fidelity (50 Ω ref to 100 kHz)	(0 to 88) dB	0.05 dB	HP 355D
(75 Ω 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	HP 3335A
Amplitude Accuracy and Frequency Response			
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	HP 438A, HP 8482A, 8485A, 8487A, 3325A, 3335A
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	HP 3335A
Sweep Time	0.1 μs to 100 s	2.3 ppm	HP 5335A, Agilent 53132A
Span	1 Hz to 2 GHz	4 ppm	HP 83650A, HP 8340A
Input Attenuator	50 MHz	0.08 dB	Agilent 355C/D
Noise Sidebands	100 kHz to 6 GHz	0.8 dB	HP 8665B

Parameter/Equipment	Range	CMC ² (±)	Comments
Scattering Parameters ³ – Reflection: S ₁₁ and S ₂₂ Reflection Coefficient 0 to 1			
Coaxial (50/75) Ω	(0.005 to <30) kHz	0.02 (lin) 0.3°	3577A, 87512A
	(0.03 to 45) MHz	0.02 (lin) 0.4°	8753ES
	(0.045 to 65) GHz	0.01 (lin) 0.3°	HP 8510C, 8517B, E8361A, 85052C, 85054B, 85056A, 85036B, 85038B, 85039B
Waveguide			
(WR-284)	(2.6 to 3.95) GHz	0.03 (lin) 1.1°	
(WR-187)	(3.95 to 5.85) GHz	0.03 (lin) 1.1°	
(WR-112)	(7.05 to 10.00) GHz	0.03 (lin) 1.1°	
(WR-90)	(8.2 to 12.4) GHz	0.02 (lin) 1.2°	HP 8510C, 8517B, E8361A, WR 90 TRL cal kit
(WR-75)	(10 to 15 GHz)	0.02 (lin) 0.8°	
(WR-62)	(12.4 to 18) GHz	0.02 (lin) 1.2°	
(WR-51)	(15 to 22) GHz	0.04 (lin) 1.2°	
(WR-42)	(18 to 26.5) GHz	0.04 (lin) 1.2°	WR15 TRL cal kit
(WR-28)	(26.5 to 40) GHz	0.015 (lin) 0.9°	Olson V05 VNA1-T/R WR 15 TRL cal kit
(WR-22)	(33 to 50) GHz	0.015 (lin) 1.1°	
(WR-15)	(50 to 75) GHz	0.015 (lin) 1.5°	

Parameter/Equipment	Range	CMC ² (±)	Comments
Scattering Parameters ³ – Reflection: S ₁₁ and S ₂₂ Reflection Coefficient 0 to 1 (cont) – Waveguide (WR-10) (WR-05)	 (75 to 100) GHz (140 to 220) GHz	 0.02 (lin) 2.2° 0.05 (lin) 11°	
Scattering Parameters ³ – Transmission: S ₂₁ and S ₁₂ Coaxial – (50/75) Ω (0.005 to <30) kHz (0.03 to 45) MHz (0.045 to 67) GHz Waveguide – (2.6 to 3.95) GHz (WR-284)	 (0 to 70) dB (1 to 70) dB (0 to 10) dB (10 to 20) dB (20 to 30) dB (30 to 50) dB (50 to 70) dB (0 to 30) dB (30 to 50) dB	 0.02 dB 0.3° 0.02 dB 0.03° 0.02 dB 0.3° 0.02 dB 0.3° 0.04 dB 0.7° 0.11 dB 1.0° 0.22 dB 1.7° 0.07 dB 0.4° 0.17 dB 0.8°	 3577A, 87512A 8753ES HP 8510C, 8517B, 85052C, 85054B, 85056A, 85036B, 85038B, 85039B, E8361A, E85058E

Parameter/Equipment	Range	CMC ² (\pm)	Comments
Scattering Parameters ³ – Transmission: S ₂₁ and S ₁₂ (cont)			
Waveguide			
(3.95 to 5.85) GHz (WR-187)	(0 to 30) dB	0.07 dB 0.4°	HP 8510C, 8517B, WR90 TRL cal kit E8361A
	(30 to 50) dB	0.17 dB 0.4°	
(7.05 to 10.0) GHz (WR-112)	(0 to 30) dB	0.07 dB 0.4°	
	(30 to 50) dB	0.17 0.8°	
(8.2 to 12.4) GHz (WR-90)	(0 to 30) dB	0.04 dB 1.0°	
	(30 to 50) dB	0.05 dB 2.0°	
(10.0 to 15.0) GHz (WR-75)	(0 to 30) dB	0.02 dB 1.2°	
	(30 to 50) dB	0.05 dB 2.0°	
(12.4 to 18.0) GHz (WR-62)	(0 to 30) dB	0.04 dB 1.0°	
	(30 to 50) dB	0.06 dB 2.0°	
(15 to 22) GHz (WR-51)	(0 to 30) dB	0.04 dB 1.0°	
	(30 to 50) dB	0.1 dB 2.0°	
(18 to 26.5) GHz (WR-42)	(0 to 30) dB	0.04 dB 1.0°	
	(30 to 50) dB	0.1 dB 2.0°	

Parameter/Equipment	Range	CMC ² (±)	Comments
Scattering Parameters ³ – Transmission: S ₂₁ and S ₁₂ (cont)			
Waveguide			
(26.5 to 40) GHz (WR-28)	(0 to 10) dB	0.02 dB 1.0°	HP 8510C, 8517D, WR22 TRL cal kit E8361A
	(10 to 30) dB	0.05 dB 1.0°	
	(30 to 50) dB	0.10 dB 2.0°	
(33 to 50) GHz (WR-22)	(0 to 10) dB	0.05 dB 1.0°	HP 8510C, V85104A, WR15 TRL cal kit
	(10 to 30) dB	0.08 dB 2.0°	
	(30 to 40) dB	0.15 dB 3.0°	
	(40 to 50) dB	0.30 dB 3.5°	
(50 to 75) GHz (WR-15)	(0 to 30) dB	0.14 dB 3.8°	HP 8510C, Olson V05 VNA2-T/R WR 15 TRL cal kit
	(30 to 40) dB	0.18 dB 3.5°	
(75 to 110) GHz (WR-10)	(0 to 30) dB	0.15 dB 4.8°	HP 8510C, W85104A, WR 10 TRL cal kit
	(30 to 40) dB	0.22 dB 5.5°	
(140 to 220) GHz (WR-05)	(0 to 10) dB	0.3 dB 10°	
	(10 to 20) dB	0.5 dB 12°	
	(20 to 30) dB	1.0 dB 15°	

Parameter/Equipment	Range	CMC ² (±)	Comments
Scattering Parameters ³ – Transmission: S ₂₁ and S ₁₂ (cont) Waveguide (140 to 220) GHz (WR-05)	(30 to 40) dB	2.7 dB 30°	
Scattering Parameters ³ – Electrical/Group Delay	30 kHz to 45 MHz 45 MHz to 67 GHz (67 to 110) GHz	230 ps 21 ps 350 ps	Agilent 8757D Agilent 8361A HP 8510C
Thermal Noise ³ – Coaxial (0.01 to 50) GHz (5 to 30) dB ENR Waveguide – (26.5 to 50) GHz (5 to 30) dB ENR (50 to 75) GHz (5 to 30) dB ENR	(≥0.01 to <1.0) GHz (≥1.0 to ≤5) GHz (>5 to ≤18) GHz (>18 to ≤23) GHz (>23 to <26.5) GHz (26.5 to <33) GHz (33 to ≤50) GHz (26.5 to ≤33) GHz (33 to ≤37) GHz (>37 to ≤38) GHz (>38 to ≤44) GHz (>44 to ≤50) GHz (50 to ≤52) GHz (>52 to ≤59) GHz (>59 to ≤60) GHz (>60 to ≤63) GHz (>63 to ≤64) GHz (>64 to ≤66) GHz (>66 to ≤68) GHz (>68 to ≤69) GHz (>69 to ≤71) GHz (>71 to ≤73) GHz (>73 to ≤75) GHz	0.15 dB 0.13 dB 0.12 dB 0.20 dB 0.26 dB 0.13 dB 0.21 dB 0.10 dB 0.17 dB 0.08 dB 0.15 dB 0.17 dB 0.21 dB 0.18 dB 0.17 dB 0.14 dB 0.10 dB 0.13 dB 0.20 dB 0.24 dB 0.31 dB 0.39 dB 0.46 dB	HP 8970B, 8971C, N8975A, 346A, 346B, 346C, 8510C, 8517B, Clare TN162 WR-28, TN172 WR-22 HP 8970B, 8971C, 8510C, 8517B; Clare TN162 WR-28, TN172 WR-22 HP 8970B, 8971C, 8510C, 8517B, V85104A, W85104A; Clare TN164 WR-15, TN165 WR-10

Parameter/Equipment	Range	CMC ² (±)	Comments
Thermal Noise ³ – (cont) Waveguide – (75 to 110) GHz (5 to 30) dB ENR	(75 to ≤76) GHz (>76 to ≤79) GHz (>79 to ≤80) GHz (>80 to <81) GHz (>81 to ≤82) GHz (>82 to ≤83) GHz (>83 to ≤86) GHz (>87 to ≤88) GHz (>88 to ≤91) GHz (>91 to ≤97) GHz (>97 to ≤100) GHz (>100 to ≤110) GHz	0.39 dB 0.29 dB 0.37 dB 0.43 dB 0.49 dB 0.55 dB 0.70 dB 0.60 dB 0.56 dB 0.51 dB 0.55 dB 0.63 dB	HP 8970B, 8971C, 8510C, V85104A; W85104A; Clare TN164 WR-15, TN165 WR- 10
Tune RF Level ³ – (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	0.01 dB 0.01 dB 0.01 dB 0.01 dB 0.01 dB 0.01 dB 0.01 dB 0.01 dB 0.01 dB 0.01 dB 0.01 dB 0.02 dB 0.07 dB	HP 8902A measuring receiver with HP 11793A microwave converter or 11970 series harmonic mixer or Oleson microwave lab mixers Agilent 5531S
Watt Meter	450 kHz to 2.7 GHz	1.5 %	Agilent E4418A; Amplifier Research DC3002

IV. Fluid Quantities

Parameter/Equipment	Range	CMC ^{2,8} (±)	Comments
Gas Flow	10 sccm to 100 slpm	0.5 %	Nitrogen, Air, Argon, mass flow standards

Parameter/Equipment	Range	CMC ^{2,8} (±)	Comments	
Pressure	(0.2 to 100) psia/psig	0.0036 %	Ruska 2465	
	(100 to 1000) psia/psig	0.0053 %	Ruska 2475/2485	
	(1000 to 15 000) psig	0.0043 %		
Pressure ³	50 to 10 000 psig	0.1 % fs	Heise PTE-1 w/ an HQS module	
Vacuum – Ionization Gauge	2.0 x 10 ⁻⁰⁷ torr	8.9 %	Ionization gauge	
	5.0 x 10 ⁻⁰⁷ torr	4.7 %		
	9.0 x 10 ⁻⁰⁷ torr	3.6 %		
	Spinning rotor gauge	2.0 x 10 ⁻⁰⁶ torr	6.4 %	
		5.0 x 10 ⁻⁰⁶ torr	3.6 %	
		9.0 x 10 ⁻⁰⁶ torr	2.7 %	
		2.0 x 10 ⁻⁰⁵ torr	6.3 %	
		5.0 x 10 ⁻⁰⁵ torr	3.4 %	
		9.0 x 10 ⁻⁰⁵ torr	2.7 %	
		2.0 x 10 ⁻⁰⁴ torr	8.8 %	
		5.0 x 10 ⁻⁰⁴ torr	3.7 %	
		9.0 x 10 ⁻⁰⁴ torr	3.2 %	
	Thermocouple Vacuum Gauge/Capacitance Manometer	(0.01 to 0.1) torr	0.6 % + 0.003 torr	Capacitance diaphragm gauge Ruska 2465
		(0.1 to 10) torr	0.6 % + 0.002 torr	
		(10 to 1000) torr	0.0066 %	
Mass, Fixed Points	5 kg	27 mg	Class 1 masses and electronic balances	
	2 kg	19 mg		
	1 kg	4.6 mg		
	500 g	2.1 mg		
	200 g	0.87 mg		
	100 g	0.43 mg		
	50 g	0.21 mg		
	20 g	0.10 mg		
	10 g	0.064 mg		
	5 g	0.038 mg		
	2 g	0.035 mg		
	1 g	0.034 mg		
	500 mg	0.010 mg		
	200 mg	0.010 mg		
	100 mg	0.010 mg		
	50 mg	0.010 mg		
	20 mg	0.010 mg		
10 mg	0.010 mg			

Parameter/Equipment	Range	CMC ^{2,8} (±)	Comments
Mass, Fixed Points (cont)	5 mg 2 mg 1 mg 50 lb 20 lb 10 lb 5 lb 2 lb 1 lb 0.5 lb 0.2 lb 0.1 lb 0.05 lb 0.02 lb 0.01 lb 0.005 lb 0.002 lb 0.001 lb	0.010 mg 0.010 mg 0.010 mg 0.0004 lb 0.0004 lb 0.000056 lb 0.000042 lb 0.0000095 lb 0.0000044 lb 0.0000023 lb 0.00000093 lb 0.00000056 lb 0.00000039 lb 0.00000028 lb 0.00000024 lb 0.00000014 lb 0.00000011 lb 0.000000088 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 100) 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 100) ft·lb	0.8 % 0.8 % 0.8 % 0.8 %	AKO TSD6000

VI. Optical Quantities

Parameter/Equipment	Range	CMC ^{2,8} (±)	Comments
Fiber Optic Power – (Single Mode) 1310 nm 1550 nm	(-60 to 5) dBm (-60 to 5) dBm	1.6 % 1.6 %	EXFO 1502
(Multi Mode) 850 nm 1300 nm	(-60 to -10) dBm (-60 to -10) dBm	1.6 % 1.6 %	

Parameter/Equipment	Range	CMC ^{2,8} (±)	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	1.5 %	Calorimeter
Laser Energy 1.06 μm	100 μJ to 150 mJ	3.9 %	Calorimeter
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	3.1 °C 3.2 °C 3.6 °C 2.7 °C 3.1 °C 2.6 °C 2.8 °C 2.8 °C 2.8 °C	NIST tungsten strip lamp

Parameter/Equipment	Range	CMC ^{2,8} (±)	Comments
Optical Pyrometer (cont)	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	3.2 °C 4.3 °C 3.7 °C 3.2 °C 3.4 °C 3.9 °C 4.3 °C	NIST tungsten strip lamp
Luminous Intensity	(20 to 500) fc	0.8 %	NIST luminous intensity lamp

VII. Thermodynamics

Parameter/Equipment	Range	CMC ² (±)	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, LN2 comparator, TP mercury cell, FP Tin cell, FP Zinc cell
Temperature – Measuring Equipment & Measure ³ Fixed Points	-195.5 °C 0.01 °C (TPW) (-80 to 0) °C (1 to 125) °C (126 to 300) °C (301 to 660) °C (661 to 1000) °C	0.006 °C 0.0004 °C 0.004 °C 0.002 °C 0.004 °C 0.1 °C 0.16 °C	Super thermometer, SPRT, TPW cell, Oil Bath, LN ₂ nanovoltmeter, Type S thermocouple, furnace
Relative Humidity Indicators ³	(20 to 85) % RH	0.9 % RH	Thunder Scientific 2500ST humidity chamber
Dewpoint/Frostpoint Indicators	(-60 to 10) °C	0.32 °C	Thunder Scientific 3900 low humidity generator

VIII. Time & Frequency

Parameter/Equipment	Range	CMC ² (±)	Comments
Frequency – Measure			
Frequency Offset	(1, 5, 10) MHz	3 parts 10 ⁻¹³	Datum 4310 cesium standard, NIST frequency measurement and analysis system (FMAS)
Frequency Stability	(1, 5, 10) MHz	3 parts 10 ⁻¹³	
Allan Variance	(1, 5, 10) MHz	1.2 x 10 ⁻¹³	HP 5370B
Stop Watches – Timers	With Human Interaction Without Human Interaction	0.6 sec 0.23 sec	HP 5326, cesium standard NIST frequency measurement and analysis system (FMAS)

¹ This laboratory offers commercial calibration service and field calibration service.

² 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.

³ 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.

⁴ In the statement of CMC, L is the numerical value of the nominal length of the device measured in inches. Γ refers to the magnitude of the reflection value being read.

⁵ “Infinity” refers to an optical focus at infinity for light collimation

⁶ 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. Best measurement uncertainties are expressed as either a specific value that covers the full range or as a fraction of the reading plus a fixed floor specification.

⁷ 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. Best measurement uncertainties 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.

⁸ In the statement of CMC, percentages are to be read as percent of reading, unless noted otherwise.