



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

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CALIBRATION

Valid To: June 30, 2017

Certificate Number: 2562.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following calibrations¹:

I. Electrical – DC/Low Frequency

Parameter/Equipment	Range	CMC ^{2, 3, 8, 10} (±)	Comments
DC Voltage – Generate and Measure	Fixed Points		
	10 V	0.70 µV/V	Zener voltage standard, low thermal short
	0 V	0.01 µV	
	0.1 V	1.8 µV/V	Zener, 752A ratio divider
	1 V	0.73 µV/V	
	10 V	0.73 µV/V	
	100 V	0.73 µV/V	
	1000 V	0.73 µV/V	
Generate	(0 to 220) mV	3.7 µV/V + 0.41 µV	Fluke 5720A, 5700A/EP (after characterization)
	(0.22 to 2.2) V	2.6 µV/V + 0.90 µV	
	(2.2 to 11) V	1.1 µV/V + 6.5 µV	
	(11 to 22) V	1.3 µV/V + 5.8 µV	
	(22 to 60) V	2.4 µV/V + 69 µV	
	(60 to 220) V	2.6 µV/V + 56 µV	
	(220 to 1000) V	3.6 µV/V + 62 µV	
Measure	(0 to 120) mV	2.9 µV/V + 0.29 µV	AT 3458A
	(0.12 to 1.2) V	1.7 µV/V + 1.9 µV	
	(1.2 to 12) V	1.7 µV/V + 18 µV	
	(12 to 120) V	3.1 µV/V + 180 µV	
	(120 to 1100) V	2.9 µV/V + 1.7 mV	

Parameter/Equipment	Range	CMC ^{2, 10, 11, 12} (\pm)	Comments
DC Voltage – Generate and Measure (cont)			
Measure	(0 to 200) mV (0.2 to 2) V (2 to 20) V (20 to 200) V (200 to 1050) V	1.8 μ V/V + 0.31 μ V 2.3 μ V/V + 0.56 μ V 2.4 μ V/V + 3.3 μ V 4.4 μ V/V + 91 μ V 4.2 μ V/V + 0.66 mV	Fluke 8508A
	(2 to 10) kV (10 to 100) kV	0.03 % 570 μ V/V + 0.6R	Divider DMM

Parameter/Range	Frequency	CMC ^{2, 8} (\pm)	Comments
AC Voltage – Generate and Measure			
1 mV	(10 to 30) Hz (30 to 1000) Hz (1 to 120) kHz (120 to 500) kHz (500 to 1000) kHz (1 to 2) MHz (2 to 3) MHz (3 to 5) MHz (5 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.22 % 0.19 % 0.19 % 0.20 % 0.20 % 0.20 % 0.28 % 0.28 % 0.28 % 0.40 % 0.84 %	Fluke 5790A/03, 5720A
2 mV	(10 to 30) Hz (30 to 1000) Hz (1 to 120) kHz (120 to 500) kHz (500 to 1000) kHz (1 to 2) MHz (2 to 3) MHz (3 to 5) MHz (5 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.22 % 0.19 % 0.19 % 0.20 % 0.20 % 0.14 % 0.24 % 0.24 % 0.24 % 0.37 % 0.83 %	
10 mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz	0.04 % 0.033 % 0.02 % 0.032 %	

Parameter/Range	Frequency	CMC ^{2,8} (±)	Comments
AC Voltage – Generate and Measure (cont)			
10 mV	(50 to 100) kHz	0.045 %	Fluke 5790A, 5720A
	(100 to 300) kHz	0.097 %	
	(300 to 500) kHz	0.14 %	
	(0.5 to 1) MHz	0.09 %	
	(1 to 2) MHz	0.09 %	
	(2 to 3) MHz	0.13 %	
	(3 to 5) MHz	0.13 %	
	(5 to 10) MHz	0.13 %	
	(10 to 20) MHz	0.21 %	
(20 to 30) MHz	0.44 %		
20 mV	(10 to 20) Hz	0.03 %	
	(20 to 40) Hz	0.019 %	
	40 Hz to 20 kHz	0.014 %	
	(20 to 50) kHz	0.025 %	
	(50 to 100) kHz	0.034%	
	(100 to 300) kHz	0.080 %	
	(300 to 500) kHz	0.11 %	
	(0.5 to 1) MHz	0.093 %	
	(1 to 2) MHz	0.093 %	
	(2 to 3) MHz	0.13 %	
	(3 to 5) MHz	0.13 %	
	(5 to 10) MHz	0.13 %	
	(10 to 20) MHz	0.21 %	
(20 to 30) MHz	0.44 %		
100 mV	(10 to 20) Hz	0.023 %	
	(20 to 40) Hz	0.10 %	
	40 Hz to 20 kHz	46 μV/V	
	(20 to 50) kHz	70 μV/V	
	(50 to 100) kHz	0.015 %	
	(100 to 300) kHz	0.023 %	
(300 to 500) kHz	0.037 %		
70 mV	(0.5 to 1) MHz	0.067 %	
	(1 to 2) MHz	0.063 %	
	(2 to 3) MHz	0.12 %	
	(3 to 5) MHz	0.12 %	
	(5 to 10) MHz	0.12 %	
	(10 to 20) MHz	0.18 %	
(20 to 30) MHz	0.41 %		
200 mV	(10 to 20) Hz	0.019 %	
	(20 to 40) Hz	83 μV/V	
	40 Hz to 20 kHz	33 μV/V	
	(20 to 50) kHz	49 μV/V	

Parameter/Range	Frequency	CMC ^{2,8} (±)	Comments
AC Voltage – Generate and Measure (cont)			
200 mV	(50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz (1 to 2) MHz (2 to 3) MHz (3 to 5) MHz (5 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.0072 % 0.016 % 0.027 % 0.061 % 0.063 % 0.13 % 0.13 % 0.13 % 0.19 % 0.42 %	Fluke 5790A, 5720A
1 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz (1 to 2) MHz (2 to 3) MHz (3 to 5) MHz (5 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.017 % 61 µV/V 22 µV/V 37 µV/V 56 µV/V 0.013 % 0.021 % 0.066 % 0.068 % 0.13 % 0.13 % 0.13 % 0.19 % 0.42 %	
2 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.017 % 60 µV/V 21 µV/V 37 µV/V 56 µV/V 0.013 % 0.021 % 0.070 %	
3 V	(0.5 to 1) MHz (1 to 2) MHz (2 to 3) MHz (3 to 5) MHz (5 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.076 % 0.080 % 0.14 % 0.15 % 0.15 % 0.26 % 0.55 %	

Parameter/Range	Frequency	CMC ^{2, 8, 11, 12} (±)	Comments
AC Voltage – Generate and Measure (cont)			
10 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.016 % 59 µV/V 22 µV/V 38 µV/V 63 µV/V 0.015 % 0.032 % 0.094 %	Fluke 5790A, 5720A
20 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.016 % 59 µV/V 22 µV/V 38 µV/V 63 µV/V 0.015 % 0.032 % 0.094 %	
44 V	(300 to 500) kHz	0.032 %	
60 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz	0.016 % 60 µV/V 26 µV/V 45 µV/V 73 µV/V 0.016 %	
100 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.017 % 62 µV/V 25 µV/V 54 µV/V 77 µV/V	
200 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.017 % 63 µV/V 25 µV/V 54 µV/V 76 µV/V	
300 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.016 % 77 µV/V 33 µV/V 0.011 % 0.039 %	

Parameter/Range	Frequency	CMC ^{2, 8, 12} (±)	Comments
AC Voltage – Generate and Measure (cont)			
600 V	50 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	33 μV/V 0.011 % 0.039 %	Fluke 5790A, 5720A
1000 V	50Hz to 1 kHz	33 μV/V	
AC Voltage – Measure			
(10 to 100) kV (2 to 10) kV	60 Hz	0.25 % + 18 V 0.4 % + 3 V	Divider DMM

Parameter/Equipment	Range	CMC ^{2, 12} (±)	Comments
DC Current – Generate and Measure			
Fixed Points	100 μA 1 mA 10 mA 20 mA 100 mA 200 mA 1 A 10 A 20A 10 to 100 A 100 to 300 A 300 to 500 A	1.9 nA 14 nA 0.14 μA 0.28 μA 1.4 μA 2.8 μA 20 μA 550 μA 1.1 mA 0.048 % + 2.3 mA 0.15 % + 1.5 mA 0.028 % + 21 mA	Guildline 9334A ⁴ Guildline 9330 ⁴ Fluke Y5020 ⁴ Guildline 9211A CS 9230 shunt
Generate	(0 to 220) μA (0.22 to 2.2) mA (2.2 to 22) mA (22 to 220) mA 220 mA to 2.2A	40 μA/A + 5.5 nA 32 μA/A + 6.2 nA 32 μA/A + 39 nA 39 μA/A + 0.62 μA 70 μA/A + 12 μA	Fluke 5700A/EP
Measure	(10 to 100) μA (1 to 10) mA (10 to 100) mA 100 mA to 1A	53 μA/A + 0.2 nA 52 μA/A + 0.1 μA 0.012 % + 1 μA 0.014 % + 15 μA	AT 3458A AT 3458A GDI-9230

Parameter/Range	Frequency	CMC ^{2,8} (±)	Comments
AC Current – Measure			
1mA	60 Hz	0.47 µA	DMM
10 mA	10 Hz 20 Hz 40 Hz (1, 5, 10) kHz	0.50 µA 0.39 µA 1.7 µA 1.6 µA	5790A with A40 shunts
20 mA	10 Hz 20 Hz 40 Hz to 10 kHz	0.098 µA 0.90 µA 0.75 µA	
100 mA	10 Hz 20 Hz 40 Hz to 5 kHz 10 kHz	5.1 µA 4.8 µA 4.1 µA 4.4 µA	
200 mA	10 Hz 20 Hz 40 Hz to 5 kHz 10 kHz	11 µA 9.9 µA 7.6 µA 11 µA	
1 A	40 Hz to 5 kHz 10 kHz	48 µA 58 µA	
2 A	40 Hz to 5 kHz 10 kHz	89 µA 330 µA	
10 A	40 Hz to 5 kHz (1, 5, 10) kHz	1.0 mA 2.0 mA	
11 A	(45, 500, 1000) Hz	1.3 mA	Y5020A
20 A	(45, 500, 1000) Hz	2.2 mA	

Parameter/Range	Frequency	CMC ^{2,8} (±)	Comments
AC Current – Generate			
(0 to 220) µA	(10 to 20) Hz (20 to 45) Hz (45 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.023 % + 0.022 µA 0.016 % + 0.015 µA 0.011 % + 0.013 µA 0.027 % + 0.034 µA 0.10 % + 0.081 µA	Fluke 5700A/EP
(0.22 to 2.2) mA	(10 to 20) Hz (20 to 45) Hz (45 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.023 % + 0.15 µA 0.016 % + 0.10 µA 0.011 % + 0.095 µA 0.019 % + 0.17 µA 0.10 % + 0.64 µA	
(2.2 to 22) mA	(10 to 20) Hz (20 to 45) Hz (45 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.023 % + 2.4 µA 0.016 % + 1.3 µA 0.011 % + 0.95 µA 0.019 % + 1.4 µA 0.10 % + 5.0 µA	
(22 to 220) mA	(10 to 20) Hz (20 to 45) Hz (45 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.023 % + 24 µA 0.016 % + 12 µA 0.011 % + 93 µA 0.019 % + 13 µA 0.1 % + 47 µA	
(0.22 to 2.2) A	(10 to 20) Hz (20 to 45) Hz (45 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.025 % + 140 µA 0.025 % + 140 µA 0.025 % + 140 µA 0.039 % + 160 µA 0.62 % + 890 µA	
(3 to 10.9999) A	(45 to 100) Hz (100 to 1000) Hz (1 to 5) kHz	0.42 mA/A + 0.84 mA 0.74 mA/A + 0.59 mA 23 mA/A + 22 µA	5520A
(11 to 20.5) A	(45 to 100) Hz (100 to 1000) Hz (1 to 5) kHz	0.91 mA/A + 1.1 mA 1.1 mA/A + 0.87 mA 25 mA/A + 42 µA	
(8 to 32) A (32 to 80) A	(16 to 450) Hz (16 to 450) Hz	21 mA/A + 1.2 mA 22 mA/A + 0.44 mA	6100A
(100 to 1000) A*	(45 to 65) Hz	0.24 % + 0.02 A	*Coil ampere turns

Parameter/Range	Frequency	CMC ^{2,8} (±)	Comments
Phase – Measure			
Sinewave Voltage to Voltage 20 mV to 350 V	(0.010 to 5) kHz (5 to 50) kHz (50 to 75) kHz (75 to 100) kHz	0.053 degree 0.056 degree 0.10 degree 0.15 degree	Clarke Hess 6000,
Sinewave Voltage to Current 20 mV to 350 V	(0.010 to 5) kHz (5 to 50) kHz (50 to 75) kHz (75 to 100) kHz	0.056 degree 0.60 degree 0.11 degree 0.15 degree	Clarke Hess 6000, Current Transformer
Phase – Generate			
Sinewave Voltage to Voltage	(10 to 65) Hz (65 to 500) Hz (0.5 to 1) kHz (1 to 5) kHz	0.67 degree 0.17 degree 0.33 degree 1.7 degree	Fluke 5520A

Parameter/Equipment	Range	CMC ^{2, 12} (±)	Comments
Resistance – Generate and Measure			
Fixed Points ⁴	1 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ	7.0 μΩ/Ω 4.1 μΩ/Ω 5.4 μΩ/Ω 5.6 μΩ/Ω 4.3 μΩ/Ω	Guildline 9334A
	100 kΩ 1 MΩ 10 MΩ 100 MΩ	5.7 μΩ/Ω 7.1 μΩ/Ω 21 μΩ/Ω 0.016 %	Guildline 9334A
	(100 to 1000) MΩ (1 to 10) GΩ (10 to 1000) GΩ	0.73 % 0.98 % 1.3 %	IET-HRRS-B-9-1K-10KV
Measure Only ⁵	(0.01 to 1) Ω (1 to 10) Ω (10 to 100) Ω (100 to 1000) Ω (1 to 10) kΩ (10 to 100) kΩ (100 to 1000) kΩ (1 to 10) MΩ (10 to 100) MΩ	14 μΩ/Ω + 84 μΩ 14 μΩ/Ω + 84 μΩ 12 μΩ/Ω + 800 μΩ 11 μΩ/Ω + 2.5 mΩ 11 μΩ/Ω + 25 mΩ 11 μΩ/Ω + 250 mΩ 11 μΩ/Ω + 7 Ω 44 μΩ/Ω + 145 Ω 0.036 % + 1.5 kΩ	Agilent 3458A
	(0.01 to 1.9999) Ω (0.1 to 19.999) Ω (1 to 199.99) Ω (10 to 19999) Ω (0.1 to 19.999) kΩ (1 to 199.99) kΩ (10 to 19999) kΩ (0.1 to 19.999) MΩ (1 to 199.99) MΩ (10 to 1999.9) MΩ	4.3 μΩ/Ω + 9.5 μΩ 4.1 μΩ/Ω + 31 μΩ 4.4 μΩ/Ω + 230 μΩ 4.6 μΩ/Ω + 1.8 mΩ 4.8 μΩ/Ω + 14 mΩ 4.3 μΩ/Ω + 240 mΩ 3.7 μΩ/Ω + 4.3Ω 3.3 μΩ/Ω + 120 Ω 6.5 μΩ/Ω + 7.8 kΩ 0.016 % + 840 kΩ	Fluke 8508A Footnote 8.5d 23 +-1C

Parameter/Equipment	Range	CMC ^{2,12} (±)	Comments
Oscilloscope –			
Generate Amplitude Volt	0 V (0.9 to 80) mV (0.08 to 2) V (2 to 20) V (20 to 200)V (200 to 230) V	25 µV 0.045 % + 25 µV 0.056 % + 16 µV 0.055 % + 0.2 mV 0.055 % + 1.6 µV 0.047 % + 32 mV	9500B
Measure Resistance	50 Ω 1 MΩ	1.4 mΩ 19 Ω	Agilent 3458A
AC Voltage Bandwidth – Generate and Measure	50 kHz to 550 MHz 50 kHz to 3.2 GHz 50 MHz to 33 GHz	4.5 % 5.5 % 3.5 %	9500B 9500B 9560
Pulse – Generate & Measure			
Transition Time	20 ps 20 ns	6 ps + 0.03*T rdg	9500B SD24/11801C T = transition time
Generate Only			
Transition Time	<20 ps	5.3 ps	Tek 067-1338-00

II. Electrical – RF/Microwave

Parameter/Range	Frequency	CMC ^{2,12} (±)	Comments
Milliwatt Reference –			
Power Measure – 1 mW @ 50 Ω	50 MHz	0.21 %	432A w/478AH76, 3458A
Power Source – 1 mW @ 50 Ω	50 MHz	2.1 µW	E44xX series

Parameter/Equipment	Frequency	CMC ² (±)	Comments
Power Measure ⁹ –			
(-10 to 20) dBm	(9 to 100) kHz	0.10 dB	Agilent E9304A-H19 with E4419B
(-20 to -10) dBm	(9 to 100) kHz	0.26 dB	
(20 to 30) dbm	9 khz to 20 GHz SWR<1.2	0.16 dB	E9304A-H19 E9300A- H25
(10 to 20) dBm	(100 to 300) kHz SWR < 1.6:1	0.14 dB	Agilent 8482A-H84 with E4419B
	300 kHz to 1 MHz SWR < 1.2:1	0.13 dB	
	1 MHz to 2 GHz SWR < 1.1:1	0.13 dB	
	(2 to 4.2) GHz SWR < 1.3:1	0.14 dB	
(-20 to 10) dBm	(100 to 300) kHz SWR < 1.6:1	0.057 dB	Agilent 8487A-H84 with E4419B
	300 kHz to 1 MHz SWR < 1.2:1	0.052 dB	
	1 MHz to 2 GHz SWR < 1.1:1	0.054 dB	
	(2 to 4.2) GHz SWR < 1.3:1	0.055 dB	
(10 to 20) dBm	(50 to 100) MHz SWR < 1.15:1	0.15 dB	Agilent 8487A-H84 with E4419B
	(0.1 to 2) GHz SWR < 1.1:1	0.15 dB	
	(2 to 12.4) GHz SWR < 1.15:1	0.15 dB	
	(12.4 to 18) GHz SWR < 1.2:1	0.15 dB	
	(18 to 26.5) GHz SWR < 1.25:1	0.16 dB	

Parameter/Range	Frequency	CMC ² (±)	Comments
Power Measure ⁹ (cont) – (10 to 20) dBm	(26.5 to 40) GHz SWR < 1.4:1	0.16 dB	Agilent 8487D with E4419B
	(40 to 50) GHz SWR < 1.5:1	0.2 dB	
(-20 to 10) dBm	(50 to 100) MHz SWR < 1.15:1	0.076 dB	
	(0.1 to 2) GHz SWR < 1.1:1	0.077 dB	
	(2 to 12.4) GHz SWR < 1.15:1	0.081 dB	
	(12.4 to 18) GHz SWR < 1.2:1	0.082 dB	
	(18 to 26.5) GHz SWR < 1.25:1	0.09 dB	
	(26.5 to 40) GHz SWR < 1.4:1	0.11 dB	
	(40 to 50) GHz SWR < 1.5:1	0.16 dB	
(-60 to -20) dBm	(50 to 100) MHz SWR < 1.15:1	0.18 dB	
	(0.1 to 2) GHz SWR < 1.1:1	0.18 dB	
	(2 to 12.4) GHz SWR < 1.15:1	0.19 dB	
	(12.4 to 18) GHz SWR < 1.2:1	0.19 dB	
	(18 to 26.5) GHz SWR < 1.25:1	0.19 dB	
	(26.5 to 40) GHz SWR < 1.4:1	0.20 dB	
	(40 to 50) GHz SWR < 1.5:1	0.23 dB	
(-20 to 10) dBm	(50 to 67) GHz	0.23 dB	KT-V8486A E4419B

Parameter/Range	Frequency	CMC ² (±)	Comments
Power Generate – (Includes DUT Mismatch 1.4 VSWR)			
(-10 to 20) dBm	(9 to 100) kHz	0.10 dB	Measure Transfer 33250A, E4419B, E9304H19
(-20 to -10) dBm	(9 to 100) kHz	0.26 dB	
(10 to 20) dBm	(100 to 300) kHz	0.14 dB	33250A, E4419B, 8482A-H84 E8257D, E4419B, 8482A-H84
	300 kHz to 1 MHz	0.13 dB	
	1 MHz to 2 GHz	0.21 dB	
	(2 to 4.2) GHz	0.35 dB	
(-20 to 10) dBm	(100 to 300) kHz	0.05 dB	
	300 kHz to 1 MHz	0.06 dB	
	1 MHz to 2 GHz	0.18 dB	
	(2 to 4.2) GHz	0.33 dB	
(10 to 20) dBm	(50 to 100) MHz	0.22 dB	E8257D, E4419B, 8487A-H84
	(0.1 to 2) GHz	0.22 dB	
	(2 to 12.4) GHz	0.35 dB	
	(12.4 to 18) GHz	0.35 dB	
	(18 to 26.5) GHz	0.44 dB	
	(26.5 to 40) GHz	0.60 dB	
(-20 to 10) dBm	(50 to 100) MHz	0.18 dB	E8257D, E4419B, 8487A-H84
	(0.1 to 2) GHz	0.19 dB	
	(2 to 12.4) GHz	0.33 dB	
	(12.4 to 18) GHz	0.33 dB	
	(18 to 26.5) GHz	0.43 dB	
	(26.5 to 40) GHz	0.59 dB	
(-60 to -20) dBm	(50 to 100) MHz	0.24 dB	E8257D, E4419B, 8487D-H84
	(0.1 to 2) GHz	0.24 dB	
	(2 to 12.4) GHz	0.37 dB	
	(12.4 to 18) GHz	0.37 dB	
	(18 to 26.5) GHz	0.46 dB	
	(26.5 to 40) GHz	0.61 dB	
(-20 to 10) dBm	(40 to 50) GHz	0.62 dB	
	(50 to 67) GHz	0.23 dB + M	

Parameter/Equipment	Frequency	CMC ² (±)	Comments
Power Generate – (-20 to 10) dBm	50 MHz	0.054 dB + R	Substitution/transfer using CMC measurement to set initial reference on UUT as limited by R Characterized Step Attenuators <i>Footnote: CMC shown at 50MHz Type N, other frequency and connectors will be greater magnitude; R is contribution of resolution of measuring equipment typically 0.6 times actual resolution</i>
Ratio Steps (-1 to -11) dB		0.012 dB + 0.00031 dB/dB + R	
(-10 to -50) dB		0.011 dB + 0.00062 dB/dB + R	
(-50 to -110) dB		0.015 dB + 0.00098 dB/dB + R	

Parameter/Equipment	Range	CMC ² (±)	Comments
Network Analyzer Dynamic Accuracy Test – dB Steps	5 dBm change (0 to 5) dB (-1 to -10) dB (-11 to -19) dB (-21 to -30) dB (-31 to -40) dB (-41 to -50) dB (-51 to -60) dB	0.002 lin (0.0012 to 0.0014) lin (0.0011 to 0.00078) lin (0.00069 to 0.000095) lin (0.000091 to 0.00071) lin (0.00075 to 0.0011) lin (0.0011 to 0.0015) lin (0.0015 to 0.0018) lin	KT 8482A 4419B Two CW signals Offset and phase locked (in dB steps)
Network Analyzer Calibration Comparison 3.5mm Rho 0.999	10 MHz (0.125 to 2) GHz (2.125 to 8) GHz (8.125 to 20) GHz (20.125 to 26.5) GHz	0.0060 lin 0.0045 lin 0.0061 lin (0.012 + 6.7 × 10 ⁻⁶ *f) lin (0.015 - 5.6 × 10 ⁻⁶ *f) lin	E8361A with data based SOL cal kit f = frequency Note: f in GHz
Rho 0.001	10 MHz (0.125 to 2) GHz (2.125 to 8) GHz (8.125 to 20) GHz (20.125 to 26.5) GHz	0.00099 lin 0.00090 lin 0.0011 lin (0.0019 + 2.9 × 10 ⁻⁶ *f) lin (0.0025 + 4.5 × 10 ⁻⁶ *f) lin	
Phase Noise for Signal Sources – (Offset Frequency)			
≤ 100 kHz	≤ 100 MHz	± 2.3 dB	Footnote -(LREF - LDUT) ≥ 10dB, f = frequency
≤ 100 kHz	0.1 GHz < f ≤ 26.5GHz	± 2.3 dB	
≤ 1 MHz	50 kHz < f ≤ 26.5 GHz	± 2.3 dB	
Cal Factor & Effective Efficiency ⁶ @ 50 Ω – Nominal 1 mW	(0.1 to 4200) MHz (4.2 to 12.4) GHz (12.4 to 15) GHz (15 to 26) GHz (26 to 40) GHz (40 to 50) GHz	1.3 % cal factor 1.8 % cal factor 2 % cal factor 3 % cal factor 3 % cal factor 5 % cal factor	RF power transfer & DC substitution



Parameter/Equipment	Range	CMC ² (±)	Comments
S-Parameters –			
S ₁₁₍₂₂₎ Measure – @ 50 Ω			
2.4 mm			
45 MHz to 2 GHz	(0.3 to 1) lin (0.03 to 0.3) lin (0.01 to 0.03) lin	(0.019 to 0.028) lin (0.017 to 0.018) lin 0.017 lin	E8361A, 85056A
	(0.3 to 1) lin (0.01 to 0.3) lin	(3.5 to 1.6) deg (180 to 3.5) deg	
(2 to 20) GHz	(0.3 to 1) lin (0.03 to 0.3) lin (0.01 to 0.03) lin	(0.023 to 0.034) lin (0.018 to 0.023) lin 0.018 lin	
	(0.3 to 1) lin (0.01 to 0.3) lin	(5 to 2) deg (180 to 5) deg	
(20 to 40) GHz	(0.3 to 1) lin (0.03 to 0.3) lin (0.01 to 0.03) lin	(0.037 to 0.056) lin (0.03 to 0.037) lin 0.03 lin	
	(0.3 to 1) lin (0.01 to 0.3) lin	(9 to 3.2) deg (180 to 9) deg	
(40 to 50) GHz	(0.3 to 1) lin (0.03 to 0.3) lin (0.01 to 0.03) lin	(0.044 to 0.07) lin (0.034 to 0.044) lin 0.034 lin	
	(0.3 to 1) lin (0.01 to 0.3) lin	(11 to 4) deg (180 to 11) deg	
S ₁₂₍₂₁₎ Measure –			
2.4 mm			
45 MHz to 50 GHz	(0 to -60) dB	(0.08 to 0.6) dB (0.5 to 5.8) deg	

Parameter/Equipment	Range	CMC ² (±)	Comments
S-Parameters (cont) –			
S ₁₁₍₂₂₎ Measure – @ 50 Ω	(0.3 to 1) lin (0.03 to 0.3) lin (0.01 to 0.03) lin	(0.01 to 0.022) lin (0.009 to 0.01) lin 0.009 lin	E8361A, 85052C
3.5 mm			
45 MHz to 2 GHz	(0.3 to 1) lin (0.01 to 0.3) lin	(2 to 1.3) deg (54 to 2) deg	
(2 to 20) GHz	(0.3 to 1) lin (0.03 to 0.3) lin (0.01 to 0.03) lin	(0.012 to 0.015) lin (0.008 to 0.013) lin 0.008 lin	
(20 to 26) GHz	(0.3 to 1) lin (0.01 to 0.3) lin	(2.6 to 0.82) deg (0.0045 to 2.6) deg	
(26 to 33) GHz	(0.3 to 1) lin (0.01 to 0.3) lin	(0.013 to 0.017) lin (0.008 to 0.014) lin 0.009 lin	
(26 to 33) GHz	(0.3 to 1) lin (0.01 to 0.3) lin	(2.8 to 1) deg (53 to 2.8) deg	
(26 to 33) GHz	(0.1 to 1.0) S(ij) (0.01 to 0.1) S(ij)	S(0.22.0.22) S(0.12.0.12)	
S ₁₂₍₂₁₎ Measure –			
3.5 mm			
45 MHz to 26 GHz	(0 to -60) dB	(0.05 to 0.27) dB; (0.3 to 1.9) deg	

Parameter/Equipment	Range	CMC ² (±)	Comments
S-Parameters (cont) –			
S ₁₁₍₂₂₎ Measure – @ 50 Ω			
7 mm, Type N ⁶	(0.01 to 1) lin	(0.003 to 0.01) lin	E8361A, 85050C
45 MHz to 2 GHz	(0.3 to 1) lin (0.03 to 0.3) lin (0.01 to 0.03) lin	(1 to 0.6) deg (6 to 1) deg (16 to 6) deg	
(2 to 18) GHz	(0.01 to 1) lin	(0.002 to 0.007) lin	
S ₁₂₍₂₁₎ Measure –			
7 mm, Type N ⁶	(0 to -60) dB	(0.05 to 0.27) dB; (0.3 to 1.9) deg	
45 MHz to 18 GHz			
S ₁₁₍₂₂₎ Measure @ 50 Ω			
1.85mm	(0.1 to 1) lin S _(ij)	(0.016, 0.016) lin S _(ij) to (0.034, 0.034) lin S _(ij)	E8361A 85058B
1 GHz to 67 GHz	(0.001 to 0.1) lin S _(ij)	(0.004, 0.004) lin S _(ij) to (0.015, 0.015) lin S _(ij)	
S ₁₂₍₂₁₎ Measure @ 50 Ω			
1.85mm			
1 GHz to 67 GHz	0 to -60 db	(0.09 to 0.37 dB (0.45 to 4.54) deg	E8361A 85058B

Parameter/Equipment	Range	CMC ² (±)	Comments
RF Power – Measure			
Relative Level	100 kHz to 50 GHz	0.013 dB + 0.004 dB/10 dB	E4448A/233
Insertion Loss	100 kHz to 50 GHz	0.026 dB + 0.004 dB/10 dB + <i>M</i>	<i>M</i> = mismatch error
Amplitude Modulation – Measure			
200 MHz to 3 GHz	(30 to 90) % ratio; 1 kHz rate	0.43 % AM	E4448A/233
0.010 kHz to 50 GHz	5 % ratio; 50 Hz to 5 kHz rate	2.4 % AM	
	30 % ratio; 50 Hz to 5 kHz rate	1.2 % AM	
	99 % ratio; 50 Hz to 5 kHz rate	0.42 % AM	
	5 % ratio; (5 to 100) kHz rate	2.4 % AM	
	30 % ratio; (5 to 100) kHz rate	0.88 % AM	
	99 % ratio; (5 to 100) kHz rate	0.32 % AM	
Angular (Frequency) Modulation – Measure			
200 MHz to 20 GHz	(100 to 240) kHz peak deviation modulation index > 1	0.8 kHz	AT-E4448A AT-33250A AT-34401A DTM-CSiii

Parameter/Equipment	Range	CMC ² (±)	Comments
Angular (Phase) Modulation – Measure 200 MHz to 20 GHz	(1 to 10) radian modulation index	0.77 % radian + 0.0025 radians	AT-E4448A DTM-CSiii
Angular and Amplitude Modulation (Digital Signal) – Measure 16QAM 256 QAM 64QAM, B PSK QPSK	(0.5 to 44) GHz	0.83 % EVM 0.83 % EVM 0.83 % EVM 0.83 % EVM 0.83 % EVM	AT 89441A

III. Thermodynamics

Parameter/Equipment	Range	CMC ^{2, 11} (±)	Comments
Temperature – Measure Measuring Equipment	20 °C to 30 °C 20 °C to 30 °C	0.07 °C 0.07 °C + 0.6R	Hart 5628/1502 comparison
Relative Humidity – Measuring Equipment Measure	(10 to 90) % RH (10 to 90) % RH	0.59 % + 0.0022 % per % RH 3.5 % RH 2.3 % RH 3.5 % RH	Fluke 5121 (TS2500) Veriteq SP 2000

IV. Time & Frequency

Parameter/Range	Range	CMC ² (±)	Comments
Frequency – Measure	5, 10 MHz	2.5 pHz/Hz	NIST FMAS, GPS receiver (1 Hz Steps)
	1 Hz to 120 MHz	10 pHz/Hz	
	250 kHz to 50 GHz	10 nHz/Hz + 0.1 Hz	E4448A/233 ext lock
Frequency – Measuring Equipment	10 MHz distribution	10 pHz/Hz	Rubidium, 58503B distribution amplifiers
	1 Hz to 10 MHz	2 μHz/Hz	AT 33250
	250 kHz to 67 GHz	10 nHz/Hz + 1.2 mHz	E8257D-550 ext lock
Time Interval – Measuring Equipment and Measure	1 ns to 10 s	0.92 ns + $TI \cdot 0.04 \mu\text{s/s}$	33250A/ 53132A/12 TI = Time interval in seconds

¹ This laboratory does not normally offer commercial calibration services.

² Calibration and Measurement Capability Uncertainties (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. CMCs 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 Agilent 3458A with Option 2, settings DCV, 100PLC, ACAL within prior 24 Hrs, 1 year cal cycle.

⁴ Transfer using Agilent 3458A

⁵ Agilent 3458A four wire ohms, ACAL within prior 24 Hrs, NPLC 100 < 100E6 Ohm > NPLC 10

⁶ Calibration Factor 100 kHz to 10 MHz is effective efficiency only.

⁷ Measure and Generate is limited to below 5 kHz; Measure only above 5 kHz.

⁸ The measurands stated are generated with the Fluke 5700, 5720 and/or 5790 series of instruments. This capability is suitable for the calibration of the devices intended to measure the stated measurand in the ranges indicated. CMC is expressed as either a specific value that covers the full range either as a fraction or as a percentage of the reading plus a fixed floor specification.

⁹ The statement of CMC does not include the effects of mismatch error.

¹⁰ Add $(12 \mu\text{V}/\text{V}) * (V_{\text{input}} / 1000)^2$ for voltage $> 100 \text{ V}$

¹¹ R = resolution contribution from unit under test.

¹² In the statement of CMC, the value is defined as the percentage of reading unless otherwise noted.



Accredited Laboratory

A2LA has accredited

ELECTRO RENT CORPORATION

Van Nuys, 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 Z540.3-2006 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 29th day of June 2015.

A handwritten signature in black ink, reading "Peter Abney".

President & CEO
For the Accreditation Council
Certificate Number 2562.01
Valid to June 30, 2017

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