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LABORATORY ACCREDITATION

ACCREDITED LABORATORY

A2LA has accredited

AGILENT TECHNOLOGIES-CHELMSFORD **Chelmsford, MA**

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 18 June 2005*).

Presented this 30th day of October 2008.

A handwritten signature in cursive script, reading "Peter Abney".

President
For the Accreditation Council
Certificate Number 1994.01
Valid to November 30, 2010



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

AGILENT TECHNOLOGIES - CHELMSFORD
 101 Brick Kiln Road
 Chelmsford, MA 01824
 Mike Helwig Phone: 916-788-5485

CALIBRATION

Valid To: November 30, 2010

Certificate Number: 1994.01

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	Best Uncertainty ^{2,4,5} (\pm)	Comments
DC Voltage – Generate ³	(0 to 0.22) V (0.22 to 2.2) V (2.2 to 11) V (11 to 22) V (22 to 220) V (220 to 1100) V	3.8 μ V/V + 2.5 μ V 4.9 μ V/V + 1.9 μ V 3.3 μ V/V + 4.7 μ V 2.4 μ V/V + 48 μ V 5.4 μ V/V + 40 μ V 6.9 μ V/V + 520 μ V	Fluke 5720A/5725A
DC Voltage – Measure ³	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1000) V	5.6 μ V/V + 1.5 μ V 5.2 μ V/V + 1.2 μ V 4.7 μ V/V + 2.5 μ V 6.6 μ V/V + 45 μ V 19 μ V/V + 160 μ V	HP 3458A/100 PLC option 002

Parameter/Equipment	Range	Best Uncertainty ^{2,4,5} (\pm)	Comments
DC Current – Generate ³	(0 to 220) μ A 220 μ A to 2.2 mA (2.2 to 22) mA (22 to 100) mA (100 to 220) mA	36 μ A/A + 0.009 μ A 33 μ A/A + 0.008 μ A 34 μ A/A + 0.040 μ A 42 μ A/A + 0.68 μ A 51 μ A/A + 0.00 μ A	Fluke 5720A
	220 mA to 1 A (1 to 2.2) A (2.2 to 11) A	76 μ A/A + 12 μ A 0.015 % - 66 μ A 0.030 % + 400 μ A	Fluke 5720A/5725A
DC Current – Measure ³	(10 to 100) μ A 100 μ A to 1 mA (1 to 10) mA (10 to 100) mA 100 mA to 1.1 A	20 μ A/A + 0 μ A 20 μ A/A + 0.1 μ A 20 μ A/A + 0.06 μ A 35 μ A/A + 0.60 μ A 0.011 % + 11 μ A	HP 3458A
Resistance – Generate, Fixed Points ³	0 Ω 1 Ω 1.9 Ω 10 Ω 19 Ω 100 Ω 190 Ω 1 k Ω 1.9 k Ω 10 k Ω 19 k Ω 100 k Ω 190 k Ω 1 M Ω 1.9 M Ω 10 M Ω 19 M Ω 100 M Ω	0.25 m Ω 0.27 m Ω 0.31 m Ω 0.34 m Ω 2.5 m Ω 2.7 m Ω 3.3 m Ω 9.3 m Ω 31 m Ω 93 m Ω 0.19 Ω 1.2 Ω 2.2 Ω 20 Ω 42 Ω 400 Ω 1.5 k Ω 12 k Ω	Fluke 5720A
Resistance – Measure ³	(0 to 10) Ω (10 to 100) Ω 100 to 1 k Ω (1 to 10) k Ω (10 to 100) k Ω 100 k Ω to 1 M Ω (1 to 10) M Ω (10 to 100) M Ω 100 M Ω to 1 G Ω	18 $\mu\Omega/\Omega$ + 74 $\mu\Omega$ 13 $\mu\Omega/\Omega$ + 740 $\mu\Omega$ 11 $\mu\Omega/\Omega$ + 7.6 $\mu\Omega$ 11 $\mu\Omega/\Omega$ + 74 $\mu\Omega$ 11 $\mu\Omega/\Omega$ + 740 $\mu\Omega$ 15 $\mu\Omega/\Omega$ + 2.4 $\mu\Omega$ 53 $\mu\Omega/\Omega$ + 110 $\mu\Omega$ 0.05 % + 4.3 k Ω 0.5 % + 290 k Ω	HP 3458A

Parameter/Range	Frequency	Best Uncertainty ^{2,4,5} (\pm)	Comments
AC Current – Generate ³			
(0 to 220) μ A	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.016 % + 0.063 μ A 89 μ A/A + 0.062 μ A 60 μ A/A + 0.062 μ A 0.018 % + 0.062 μ A 0.10 % + 0.09 μ A	Fluke 5720A
220 μ A to 2.2 mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.027 % + 0.056 μ A 0.020 % + 0.051 μ A 0.016 % + 0.052 μ A 0.023 % + 0.12 μ A 0.11 % + 0.67 μ A	
(2.2 to 22) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.027 % + 0.56 μ A 0.021 % + 0.51 μ A 0.016 % + 0.52 μ A 0.023 % + 0.71 μ A 0.11 % + 5.1 μ A	
(22 to 220) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.028 % + 3.9 μ A 0.021 % + 3.0 μ A 0.017 % + 2.2 μ A 0.024 % + 3.1 μ A 0.11 % + 0.01 mA	
220 mA to 2.2 A	20 Hz to 1 kHz 220 mA to 1.0 A >1 A to 2.2 A (1 to 5) kHz 220 mA to 1.0 A >1 A to 2.2 A (5 to 10) kHz	0.030 % + 32 μ A 0.035 % + 26 μ A 0.044 % + 83 μ A 0.055 % + 72 μ A 0.67 % + 0.072 mA	
(2.2 to 11) A	40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.044 % + 130 μ A 0.088 % + 290 μ A 0.31 % + 0.64 mA	
AC Current – Measure ³			
(0 to 100) μ A	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz	0.4 % + 31 nA 0.15 % + 31 nA 0.06 % + 31 nA	HP 3458A
(0.1 to 1) mA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz	0.4 % + 310 nA 0.15 % + 210 nA 0.06 % + 210 nA	

Parameter/Range	Frequency	Best Uncertainty ^{2,4,5} (\pm)	Comments
AC Current – Measure (cont) ³			
(1 to 10) mA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz	0.4 % + 3.1 μ A 0.15 % + 2.1 μ A 0.06 % + 2.1 μ A	HP 3458A
(10 to 100) mA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz	0.4 % + 31 μ A 0.15 % + 21 μ A 0.06 % + 21 μ A	
100 mA to 1.05 A	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz	0.4 % + 220 μ A 0.16 % + 220 μ A 0.08 % + 220 μ A 0.1 % + 220 μ A	
AC Voltage – Generate ³			
(0 to 22) mV	(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 500 kHz to 1 MHz	0.027 % + 4.5 μ V 0.013 % + 4.5 μ V 0.011 % + 4.5 μ V 0.027 % + 4.5 μ V 0.054 % + 5.3 μ V 0.12 % + 10 μ V 0.17 % + 24 μ V 0.30 % + 24 μ V	Fluke 5720A
(22 to 220) mV	(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 500 kHz to 1 MHz	0.025 % + 12 μ V 95 μ V/V + 7.3 μ V 86 μ V/V + 7.3 μ V 0.018 % + 9.4 μ V 0.049 % + 16 μ V 0.088 % + 20 μ V 0.14 % + 0.033 mV 0.27 % + 0.048 mV	
220 mV to 2.2 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 500 kHz to 1 MHz	0.025 % + 39 μ V 99 μ V/V + 15 μ V 63 μ V/V + 5.9 μ V 86 μ V/V + 8.3 μ V 0.011 % + 30 μ V 0.041 % + 78 μ V 0.99 % + 200 μ V 0.16 % + 0.32 mV	

Parameter/Range	Frequency	Best Uncertainty ^{2,4,5} (\pm)	Comments
AC Voltage – Generate (cont) ³			
(2.2 to 22) 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 500 kHz to 1 MHz	0.026 % + 420 μ V 0.011 % + 150 μ V 67 μ V/V + 44 μ V 91 μ V/V + 90 μ V 0.011 % + 210 μ V 0.029 % + 650 μ V 0.11 % + 2.0 mV 0.16 % + 3.3 mV	Fluke 5720A
(22 to 220) V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (>22 to 100) Vrms (>100 to 220) Vrms (50 to 100) kHz (>22 to 100) Vrms (>100 to 220) Vrms (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.024 % + 3.9 mV 0.010 % + 1.5 mV 69 μ V/V + 430 μ V 98 μ V/V + 910 μ V 0.017 % + 560 μ V 0.016 % + 2.4 mV 0.021 % + 1.9 mV 0.087 % + 16 mV 0.43 % + 39 mV 0.79 % + 79 mV	
(0 to 250) V max output, 1100 V range	(15 to 50) Hz 50 Hz to 1 kHz	0.031 % + 17 mV 91 μ V/V + 2.9 mV	Fluke 5720A/ 5725A
(0 to 250) V max output, 1100 V range	40 Hz to 20 kHz (20 to 30) kHz	91 μ V/V + 2.9 mV 0.051 % + 9.6 mV	
(0 to 750) V	(30 to 50) kHz (50 to 100) kHz	0.052 % + 8.6 mV 0.19 % + 37 mV	
AC Voltage – Measure ³			
(0 to 10) mV	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (1 to 4) MHz (4 to 8) MHz	0.03 % + 3.1 μ V 0.02 % + 1.2 μ V 0.03 % + 1.7 μ V 0.1 % + 1.6 μ V 0.5 % + 1.3 μ V 4 % + 2.1 μ V 1.2 % + 6.6 μ V 7 % + 7.5 μ V 20 % + 8.2 μ V	HP 3458A

Parameter/Range	Frequency	Best Uncertainty ^{2, 5, 11} (\pm)	Comments
AC Voltage – Measure (cont) ³			
(10 to 100) mV	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (1 to 2) MHz (2 to 4) MHz (4 to 8) MHz (8 to 10) MHz	70 μ V/V + 4.1 μ V 70 μ V/V + 2.1 μ V 0.014 % + 2.3 μ V 0.03 % + 2.6 μ V 0.08 % + 2.3 μ V 0.3 % + 15 μ V 1 % + 28 μ V 1.5 % + 20 μ V 4 % + 74 μ V 4 % + 83 μ V 15 % + 110 μ V	HP 3458A
100 mV to 1 V	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (1 to 2) MHz (2 to 4) MHz (4 to 8) MHz (8 to 10) MHz	70 μ V/V + 41 μ V 70 μ V/V + 21 μ V 0.014 % + 22 μ V 0.03 % + 22 μ V 0.08 % + 22 μ V 0.3 % + 120 μ V 1 % + 300 μ V 1.5 % + 210 μ V 4 % + 730 μ V 4 % + 830 μ V 15 % + 1 mV	
(1 to 10) V	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (1 to 2) MHz (2 to 4) MHz (4 to 8) MHz (8 to 10) MHz	70 μ V/V + 420 μ V 70 μ V/V + 220 μ V 0.014 % + 240 μ V 0.03 % + 250 μ V 0.08 % + 220 μ V 0.3 % + 1.1 mV 1 % + 1.1 mV 1.5 % + 1.1 mV 4 % + 7.1 mV 4 % + 8.1 mV 15 % + 11 mV	
(10 to 100) V	(1 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz	0.02 % + 4.1 mV 0.02 % + 2.6 mV 0.035 % + 2.4 mV 0.12 % + 2.1 mV 0.4 % + 11 mV 1.5 % + 40 mV	
(100 to 750) V	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.04 % + 31 mV 0.04 % + 16 mV 0.06 % + 16 mV 0.12 % + 16 mV 0.3 % + 15 mV	

Parameter/Range	Frequency	Best Uncertainty ^{2,4,5} (\pm)	Comments
AC Voltage Flatness – Generate ³			
0.3 mV to 3.5 V	(10 to 30) Hz 30 Hz to 120 kHz	0.27 % of reading 0.14 % of reading	Fluke 5720A or 5700A-03 (referenced to 1 kHz)
(0.3 to 1.1) mV	120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.46 % of reading 0.62 % of reading 0.80 % of reading 2.4 % of reading	
(0.3 to 3) mV	120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.22 % of reading 0.37 % of reading 0.55 % of reading 1.4 % of reading	
3 mV to 3.5 V	120 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.12 % of reading 0.21 % of reading 0.38 % of reading 0.86 % of reading	
AC Voltage Flatness – Measure ³			
Up to 3 V	10 Hz 100 Hz (10, 30) kHz 100 kHz 300 kHz 1 MHz 3 MHz 8 MHz 10 MHz 20 MHz 30 MHz 50 MHz 70 MHz 80 MHz 100 MHz	0.02 % + 6.9 μ V/V 80 μ V + 5.5 μ V/V 80 μ V + 3.2 μ V/V 0.01 % + 8.0 μ V/V 0.01 % + 5.2 μ V/V 0.01 % + 6.5 μ V/V 0.13 % + 59 μ V/V 0.13 % + 110 μ V/V 0.13 % + 91 μ V/V 0.25 % + 210 μ V/V 0.25 % + 240 μ V/V 0.61 % + 340 μ V/V 0.9 % + 240 μ V/V 1.1 % + 790 μ V/V 1.3 % + 940 μ V/V	By comparison to 11049A, 11050A, 11051A thermal voltage converters

Parameter/Range	Frequency	Best Uncertainty ^{2,4,5} (\pm)	Comments
Resistance – Generate ³			
0.1 Ω (1, 10) Ω 100 Ω (1, 10, 100) k Ω	DC to 1 MHz, direct measurement	1 % of value 0.1 % of value 0.03 % of value 0.03 % of value	16074A DUT box calibration R-L standard, BNC 3 terminal
Shunt 15 A 0.1 Ω , 25 W	Dissipated power: 0.3 Amps to full power	0.014 %	Guildline 9230-15
Shunt 100A 0.01 Ω , 100 W	$\leq 25W$	0.014 %	Guildline 9230-100
Shunt 300A 0.01 Ω , 90 W	$\leq 25W$	0.012 %	Guildline 9230-300
Shunt 1000A 0.0001 Ω , 100 W	$\leq 25W$	0.036 %	Guildline 9230-1000 Option 92310 forced air cooling
Capacitance – Generate ³			
Direct Measure (1, 10) pF (100, 1000) pF (0.01, 0.1, 1) μ F	1 kHz	0.01 % of reading 0.01 % of reading 0.01 % of reading	16380A/16380C standard air capacitor set, BNC 4 terminal pair
Algorithmic Derivation 1 pF	1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz	0.05 % of reading 0.06 % of reading 0.10 % of reading 0.2 % of reading 0.3 % of reading 1.0 % of reading 1.5 % of reading	
(10, 100) pF	(1, 2) MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz	0.025 % of reading 0.03 % of reading 0.04 % of reading 0.06 % of reading 0.15 % of reading 0.20 % of reading	

Parameter/Range	Frequency	Best Uncertainty ^{2,4,5} (\pm)	Comments
Capacitance Generate (cont) ³ –			
Algorithmic Derivation 1000 pF	1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz	0.05 % of reading 0.06 % of reading 0.10 % of reading 0.15 % of reading 0.20 % of reading 0.50 % of reading 0.70 % of reading	16380A/16380C standard air capacitor set, BNC 4 terminal pair
Substitution Method (0.01, 0.1, 1) μ F	120 Hz to 10 kHz	0.025 % of reading 0.04 % of reading	
(0.01, 0.1) μ F 1 μ F	100 kHz	0.05 % of reading 0.1 % of reading	
Direct Measure (3.3 to 10.9999) nF (11 to 32.9999) nF (0.33 to 109.999) μ F (110 to 329.999) μ F (3.3 to 10.9999) μ F	(10 to 1000) Hz (10 to 1000) Hz (10 to 600) Hz (10 to 300) Hz (10 to 150) Hz	0.4 % of reading 0.4 % of reading 0.4 % of reading 0.4 % of reading 0.4 % of reading	Fluke 5720A

II. Electrical – RF/Microwave

Parameter/Equipment/Range	Best Uncertainty ^{2, 11} (\pm)	Comments
<p>Amplitude Modulation – Measure^{3, 8}</p> <p>(0.15 to 10) MHz (5% to <10%) AM (10% to 99%) AM</p> <p>(5% to <10%) AM (10% to 99%) AM</p> <p>(10 to 1300) MHz (5% to <10%) AM (10% to 99%) AM</p> <p>(5% to <10%) AM (10% to 99%) AM</p> <p>1300 MHz to 26.5 GHz (5% to <10%) AM (10% to 99%) AM</p> <p>10 MHz to 26.5 GHz (5% to <10%) AM (10% to 99%) AM</p>	<p>$0.025AM + 0.030\%$ $0.025AM + 0.14\%$</p> <p>$0.038AM + 0.030\%$ $0.038AM + 0.13\%$</p> <p>$0.012AM + 0.033\%$ $0.012AM + 0.17\%$</p> <p>$0.038AM + 0.030\%$ $0.037AM + 0.16\%$</p> <p>$0.019AM + 0.029\%$ $0.019AM + 0.14\%$</p> <p>$0.038AM + 0.030\%$ $0.038AM + 0.11\%$</p>	<p>HP 8902 measuring receiver:</p> <p>rate: 50 Hz to 10 kHz, depth: 5% to 99%</p> <p>rate: 20 Hz to 10 kHz, depth: to 99%</p> <p>rate: 50 Hz to 10 kHz, depth: 5% to 99%</p> <p>rate: 20 Hz to 10 kHz, depth: to 99%</p> <p>rate: 50 Hz to 10 kHz, depth: 5% to 99%</p> <p>rate: 20 Hz to 10 kHz, depth: to 99%</p>
<p>Frequency Modulation – Measure^{3, 9}</p> <p>(0.25 to 10) MHz (0 to <4) kHz Peak FM (≥ 4 to <40) kHz Peak FM</p> <p>(10 to 1300) MHz (0 to <4) kHz Peak FM (≥ 4 to <40) kHz Peak FM (≥ 40 to <400) kHz Peak FM</p> <p>(10 to 1300) MHz (0 to <4) kHz Peak FM (≥ 4 to <40) kHz Peak FM (≥ 40 to <400) kHz Peak FM</p>	<p>$0.024FM + 2.6\text{ Hz Pk}$ $0.024FM + 10\text{ Hz Pk}$</p> <p>$0.012FM + 2.6\text{ Hz Pk}$ $0.012FM + 12\text{ Hz Pk}$ $0.012FM + 110\text{ Hz Pk}$</p> <p>$0.059FM + 2.8\text{ Hz Pk}$ $0.059FM + 13\text{ Hz Pk}$ $0.059FM + 110\text{ Hz Pk}$</p>	<p>HP 8902 measuring receiver: 40.0 to 400.0: 1 digit = 100 Hz 4.00 to 39.99: 1 digit = 10 Hz 0 to 3.999: 1 digit = 1 Hz</p> <p>rate: 20 Hz to 10 kHz, ≤ 40 kHz peak</p> <p>rate: 50 Hz to 100 kHz, ≤ 400 kHz peak</p> <p>rate: 20 Hz to 200 kHz, ≤ 400 kHz peak</p>

Parameter/Equipment/Range	Best Uncertainty ^{2, 11} (\pm)	Comments
<p>Frequency Modulation – Measure (cont)^{3, 9}</p> <p>10 MHz to 26.5 GHz (10 to 1300) MHz (0 to <4) kHz Peak FM (≥ 4 to < 40) kHz Peak FM (≥ 40 to < 400) kHz Peak FM</p> <p>(>1.3 to 6.2) GHz (0 to <4) kHz Peak FM (≥ 4 to < 40) kHz Peak FM (≥ 40 to < 400) kHz Peak FM</p> <p>(>6.2 to 12.4) GHz (0 to <4) kHz Peak FM (≥ 4 to < 40) kHz Peak FM (≥ 40 to < 400) kHz Peak FM</p> <p>(>12.4 to 18.6) GHz (0 to <4) kHz Peak FM (≥ 4 to < 40) kHz Peak FM (≥ 40 to < 400) kHz Peak FM</p> <p>(>18.6 to 26.5) GHz (0 to <4) kHz Peak FM (≥ 4 to < 40) kHz Peak FM (≥ 40 to < 400) kHz Peak FM</p> <p>10 MHz to 26.5 GHz (10 to 1300) MHz (0 to <4) kHz Peak FM (≥ 4 to < 40) kHz Peak FM (≥ 40 to < 400) kHz Peak FM</p> <p>(>1.3 to 6.2) GHz (0 to <4) kHz Peak FM (≥ 4 to < 40) kHz Peak FM (≥ 40 to < 400) kHz Peak FM</p> <p>(>6.2 to 12.4) GHz (0 to <4) kHz Peak FM (≥ 4 to < 40) kHz Peak FM (≥ 40 to < 400) kHz Peak FM</p> <p>(>12.4 to 18.6) GHz (0 to <4) kHz Peak FM (≥ 4 to < 40) kHz Peak FM (≥ 40 to < 400) kHz Peak FM</p>	<p>0.012FM + 2.4 Hz Pk 0.012FM + 12.0 Hz Pk 0.012FM + 100 Hz Pk</p> <p>0.0099FM + 10 Hz Pk 0.012FM + 12 Hz Pk 0.012FM + 100 Hz Pk</p> <p>0.0075FM + 24 Hz Pk 0.012FM + 12 Hz Pk 0.012FM + 85 Hz Pk</p> <p>0.0049FM + 52 Hz Pk 0.011FM + 36 Hz Pk 0.012FM + 110 Hz Pk</p> <p>0.0035FM + 80 Hz Pk 0.011FM + 46 Hz Pk 0.012FM + 100 Hz Pk</p> <p>0.059FM + 2.8 Hz Pk 0.059FM + 14 Hz Pk 0.059FM + 120 Hz Pk</p> <p>0.058FM + 5.2 Hz Pk 0.059FM + 14 Hz Pk 0.059FM + 120 Hz Pk</p> <p>0.055FM + 15 Hz Pk 0.059FM + 14 Hz Pk 0.059FM + 120 Hz Pk</p> <p>0.050FM + 37 Hz Pk 0.059FM + 15 Hz Pk 0.059FM + 120 Hz Pk</p>	<p>HP 8902 measuring receiver: 11793A DownConverter, gen. ext L.O.</p> <p>rate: 50 Hz to 100 kHz, ≤ 400 kHz peak</p> <p>rate: 20 Hz to 200 kHz, ≤ 400 kHz peak</p>

Parameter/Equipment/Range	Best Uncertainty ^{2, 11} (\pm)	Comments
Frequency Modulation – Measure (cont) ³ (>18.6 to 26.5) GHz (0 to <4) kHz Peak FM (≥ 4 to < 40) kHz Peak FM (≥ 40 to < 400) kHz Peak FM	0.045FM + 62 Hz Pk 0.059FM + 16 Hz Pk 0.059FM + 120 Hz Pk	HP 8902 measuring receiver: 11793A DownConverter, gen. ext L.O. rate: 20 Hz to 200 kHz, ≤ 400 kHz peak

Parameter/Range	Frequency	Best Uncertainty ² (\pm)	Comments
RF Absolute Power – Measure ^{3, 6}			
1 mW, Type-N(f), 50 Ω	50 MHz	0.015 dB (3.4 μ W)	HP 432A w/ HP 478A-H76
(+20 to -30) dBm, 75 Ω	(100 to 600) kHz SWR $\leq 1.8:1$	0.057 dB	HP 436A or HP 438A w/ HP 8483A, Type-N(m)
	600 kHz to 2 GHz SWR $\leq 1.18:1$	0.059 dB	
(+20 to -30) dBm, 50 Ω	(100 to 300) kHz SWR $\leq 1.6:1$	0.05 dB	HP 436A or HP 438A w/ HP 8482A, Type-N(m)
	300 kHz to 1 MHz SWR $\leq 1.2:1$	0.049 dB	
	1 MHz to 2 GHz SWR $\leq 1.1:1$	0.051 dB	
	(2 to 4.2) GHz SWR $\leq 1.3:1$	0.050 dB	
(-20 to -70) dBm, 50 Ω	(10 to 30) MHz SWR $\leq 1.4:1$	0.074 dB	HP 436A or HP 438A w/ HP 8481D, Type-N(m)
	30 MHz to 4 GHz SWR $\leq 1.15:1$	0.074 dB	
	(4 to 10) GHz SWR $\leq 1.21:1$	0.077 dB	
	(10 to 15) GHz SWR $\leq 1.3:1$	0.10 dB	
	(15 to 18) GHz SWR $\leq 1.35:1$	0.11 dB	

Parameter/Range	Frequency	Best Uncertainty ² (±)	Comments		
RF Absolute Power – Measure (cont) ^{3, 6}	(+20 to -30) dBm, 50 Ω	(50 to 100) MHz SWR ≤ 1.15:1	0.060 dB	HP 436A or HP 438A w/ HP 8487A, 2.4 mm(m)	
		(0.1 to 2) GHz SWR ≤ 1.1:1	0.075 dB		
		(2 to 12.4) GHz SWR ≤ 1.15:1	0.062 dB		
		(12.4 to 18) GHz SWR ≤ 1.2:1	0.065 dB		
		(18 to 26.5) GHz SWR ≤ 1.25:1	0.099 dB		
		(26.5 to 40) GHz SWR ≤ 1.4:1	0.097 dB		
		(40 to 50) GHz SWR ≤ 1.5:1	0.13 dB		
	(-20 to -70) dBm, 50 Ω	(50 to 100) MHz SWR ≤ 1.19:1	0.054 dB		HP 436A or HP 438A w/ HP 8487D, 2.4 mm(m)
		(0.1 to 2) GHz SWR ≤ 1.15:1	0.054 dB		
		(2 to 12.4) GHz SWR ≤ 1.2:1	0.058 dB		
		(12.4 to 18) GHz SWR ≤ 1.29:1	0.068 dB		
		(18 to 34) GHz SWR ≤ 1.37:1	0.095 dB		
		(34 to 40) GHz SWR ≤ 1.61:1	0.11 dB		
		(40 to 50) GHz SWR ≤ 1.86:1	0.19 dB		
(+30 to -20) dBm, 50 Ω	100 kHz to 2.6 GHz SWR ≤ 1.15:1	0.071 dB	HP 8902A w/ HP 11722A, Type-N(m)		
(+30 to -20) dBm, 50 Ω	(50 to 1300) MHz SWR ≤ 1.15:1	0.071 dB	HP 8902A w/ HP 11792A, APC 3.5 mm(m)		
	(1.3 to 18) GHz SWR ≤ 1.25:1	0.081 dB			
	(18 to 26.5) GHz SWR ≤ 1.4:1	0.092 dB			

Parameter/Range	Frequency	Best Uncertainty ² (±)	Comments	
Tuned RF Power ³ –				
Absolute – Measure ⁷				
(≤ +10 to ≥ -22) dBm	2.5 MHz to 26.5 GHz	0.17 dB	HP 8902A with HP 11722A or with HP 11792A and HP 11793A	
(< -22 to ≥ -42) dBm		0.18 dB		
(< -42 to ≥ -50) dBm		0.20 dB		
(< -50 to ≥ -60) dBm		0.21 dB		
(< -60 to ≥ -72) dBm		0.22 dB		
(< -72 to ≥ -80) dBm		0.23 dB		
(< -80 to ≥ -92) dBm		0.24 dB		
(< -92 to ≥ -102) dBm		0.27 dB		
(< -102 to ≥ -110) dBm		0.28 dB		
(< -110 to ≥ -120) dBm		0.31 dB		
(< -120 to ≥ -127) dBm		0.34 dB		
Relative – Measure				
(≤ +10 to ≥ +2) dBm	2.5 MHz to 26.5 GHz	0.081 dB		HP 8902A with HP 11722A or with HP 11792A and HP 11793A
(< +2 to ≥ -12) dBm		0.071 dB		
(< -12 to ≥ -22) dBm		0.081 dB		
(< -22 to ≥ -31) dBm		0.088 dB		
(< -31 to ≥ -40) dBm		0.095 dB		
(< -40 to ≥ -50) dBm		0.12 dB		
(< -50 to ≥ -61) dBm		0.15 dB		
(< -61 to ≥ -71) dBm		0.16 dB		
(< -71 to ≥ -80) dBm		0.17 dB		
(< -80 to ≥ -90) dBm		0.19 dB		
(< -90 to ≥ -100) dBm		0.22 dB		
(< -100 to ≥ -110) dBm		0.23 dB		
(< -110 to ≥ -120) dBm		0.27 dB		
(< -120 to ≥ -127) dBm		0.30 dB		

Parameter/Range	Frequency	Best Uncertainty ² (±)	Comments
RF Absolute Power – Generate ^{3,6}			
Into 50 Ω (10 to 3) V p-p	0.001 Hz to 100 kHz SWR 1.2:1	0.12 dB	HP 3325A/B with BNC(f)
2.99 V to 1 mV p-p	0.001 Hz to 100 kHz SWR 1.2:1	0.23 dB	
Into 50 Ω (10 to 3) V p-p	100 kHz to 20 MHz SWR ≤ 1.2:1	0.47 dB	HP 3325A/B with BNC(f)
2.999 V to 1 mV p-p	100 kHz to 10 MHz SWR ≤ 1.2:1	0.70 dB	
(2.999 to 0.1) V p-p	(10 to 20) MHz SWR ≤ 1.2:1	0.70 dB	
(99.99 to 1) mV p-p	(10 to 20) MHz SWR ≤ 1.2:1	1.0 dB	
Full Amplitude, 50Ω 13.01 dBm	1 kHz to 25 MHz 200 Hz to 80 MHz	0.14 dB 0.23 dB	HP 3325A/B with BNC(f)
Full Amplitude, 75Ω 11.25 dBm	1 kHz to 25 MHz 200 Hz to 25 MHz	0.14 dB 0.23 dB	
In 2 dB steps, 50 Ω (0 to -18) dBm (-20 to -58) dBm (-60 to -98) dBm	200 Hz to 80 MHz 200 Hz to 80 MHz 200 Hz to 80 MHz	0.28 dB 0.34 dB 0.47 dB	HP 3325A/B with BNC(f)
In 2 dB steps, 75 Ω (0 to -18) dBm	200 Hz to 25 MHz (25 to 80) MHz	0.28 dB 0.41 dB	
(-20 to -58) dBm	200 Hz to 25 MHz (25 to 80) MHz	0.34 dB 0.52 dB	
(-60 to -98) dBm	200 Hz to 25 MHz (25 to 80) MHz	0.47 dB 0.81 dB	
In 0.01 dB steps (0 to -1.99) dBm	100 kHz to 2.56 GHz SWR ≤ 1.5:1	0.036 dB	HP 3335A with BNC(f)

Parameter/Range	Frequency	Best Uncertainty ² (±)	Comments
RF Absolute Power – Generate ^{3,6} – (cont)			
Into 50 Ω (+16 to -119.9) dBm	100 kHz to 2.56 GHz SWR ≤ 1.5:1	1.2 dB	HP 8663A, Type-N(f)
(-120 to -129.9) dBm	100 kHz to 2.56 GHz SWR ≤ 1.5:1	3.5 dB	HP 8663A, Type-N(f)
> +10 dBm	10 MHz to 2 GHz SWR ≤ 1.6:1	1.4 dB	HP 83650B, 2.4 mm(m)
	(≥ 2 to ≤ 20) GHz SWR ≤ 1.6:1	1.5 dB	
> -10 dBm	10 MHz to 2 GHz SWR ≤ 1.6:1	0.72 dB	HP 83650B, 2.4 mm(m)
	(≥ 2 to ≤ 20) GHz SWR ≤ 1.6:1	0.84 dB	
	(> 20 to ≤ 40) GHz SWR ≤ 1.8:1	1.1 dB	
	(> 40 to ≤ 50) GHz SWR ≤ 2:1	2.0 dB	
> -60 dBm	10 MHz to 2 GHz SWR ≤ 1.6:1	1.1 dB	HP 83650B, 2.4 mm(m)
	(≥ 2 to ≤ 20) GHz SWR ≤ 1.6:1	1.2 dB	
	(> 20 to ≤ 40) GHz SWR ≤ 1.8:1	1.4 dB	
	(> 40 to ≤ 50) GHz SWR ≤ 2:1	2.4 dB	
≤ -60 dBm	10 MHz to 2 GHz SWR ≤ 1.6:1	1.7 dB	HP 83650B, 2.4 mm(m)
	(≥ 2 to ≤ 20) GHz SWR ≤ 1.6:1	1.8 dB	
	(> 20 to ≤ 40) GHz SWR ≤ 1.8:1	2.0 dB	
	(> 40 to ≤ 50) GHz SWR ≤ 2:1	3.0 dB	

Parameter/Range	Frequency	Best Uncertainty ² (±)	Comments
Thermal Noise Measure ³ – ENR (14 to 16) dB	10 MHz to 18 GHz SWR 1.25:1 (18 to 26.5) GHz SWR 1.35:1	0.12 dB 0.13 dB	HP 346C w/ APC-3.5
Pulse – Generate ³ Transition Time Width RMS Jitter – Period, Delay and Width	(10 to 90) % 150 ps to 10 ns 10 ns to < 100 ns ≥ 100 μs to < 10 ms ≥ 10 ms to < 100 ms ≥ 100 ms to < 0.99 ms 2 σ	130 ps 130 ps (0.013 * Width) + 1.2 ns (0.013 * Width) + 140 ns (0.012 * Width) + 20 ns (0.012 * Width) + 190 ns 10 ps	HP 8133A HP 8133A HP 8161A HP 8161A HP 8161A HP 8161A HP 8133A

Parameter/Range	Frequency	Best Uncertainty ² (±)	Comments
Attenuation – Generate			
Coaxial, 1 dB Step ³ (0 to 11) dB			
0 dB	50 MHz to 2 GHz (2 to 4) GHz	0.026 0.029	HP 8494G w/ Type-N(f)
1 dB	50 MHz to 2 GHz (2 to 4) GHz	0.026 0.029	
2 dB	50 MHz to 2 GHz (2 to 4) GHz	0.027 0.029	
3 dB	50 MHz to 2 GHz (2 to 4) GHz	0.028 0.029	
4 dB	50 MHz to 2 GHz (2 to 4) GHz	0.028 0.029	
5 dB	50 MHz to 2 GHz (2 to 4) GHz	0.029 0.029	
6 dB	50 MHz to 2 GHz (2 to 4) GHz	0.029 0.030	
7 dB	50 MHz to 2 GHz (2 to 4) GHz	0.030 0.030	
8 dB	50 MHz to 2 GHz (2 to 4) GHz	0.030 0.030	
9 dB	50 MHz to 2 GHz (2 to 4) GHz	0.031 0.030	
10 dB	50 MHz to 2 GHz (2 to 4) GHz	0.031 0.030	
11 dB	50 MHz to 2 GHz (2 to 4) GHz	0.031 0.030	

Parameter/Range	Frequency	Best Uncertainty ² (±)	Comments
Attenuation – Generate (cont.)			
Coaxial, 10 dB Step ³			
0 dB	50 MHz to 2 GHz (2 to 4) GHz	0.026 0.029	HP 8496G w/ Type-N(f)
10 dB	50 MHz to 2 GHz (2 to 4) GHz	0.031 0.030	
20 dB	50 MHz to 2 GHz (2 to 4) GHz	0.032 0.032	
30 dB	50 MHz to 2 GHz (2 to 4) GHz	0.034 0.035	
40 dB	50 MHz to 2 GHz (2 to 4) GHz	0.041 0.045	
50 dB	50 MHz to 2 GHz (2 to 4) GHz	0.052 0.054	
60 dB	50 MHz to 2 GHz (2 to 4) GHz	0.052 0.055	
70 dB	50 MHz to 2 GHz (2 to 4) GHz	0.054 0.057	
80 dB	50 MHz to 2 GHz (2 to 4) GHz	0.059 0.064	
90 dB	50 MHz to 2 GHz (2 to 4) GHz	0.066 0.071	
100 dB	50 MHz to 2 GHz (2 to 4) GHz	0.067 0.071	
110 dB	50 MHz to 2 GHz (2 to 4) GHz	0.074 0.073	

Parameter/Range	Frequency	Best Uncertainty ² (±)	Comments
Attenuation – Generate (cont.)			
Coaxial, Fixed ³			
3 dB	DC to 2 GHz, SWR < 1.25:1	0.028	HP 8491A/B Type-N
	(2 to 4) GHz, SWR < 1.2:1	0.029	
	(4 to 18) GHz, SWR < 1.2:1	0.053	
6 dB	DC to 2 GHz, SWR < 1.25:1	0.029	
	(2 to 4) GHz, SWR < 1.2:1	0.030	
	(4 to 18) GHz, SWR < 1.2:1	0.053	
10 dB	DC to 2 GHz, SWR < 1.25:1	0.031	
	(2 to 4) GHz, SWR < 1.2:1	0.030	
	(4 to 18) GHz, SWR < 1.2:1	0.053	
20 dB	DC to 2 GHz, SWR < 1.5:1	0.032	
	(2 to 4) GHz, SWR < 1.5:1	0.032	
	(4 to 18) GHz, SWR < 1.5:1	0.052	

Parameter/Range	Best Uncertainty ² (±)	Comments
Reflection S ₁₁ / S ₂₂ – Measure ³		
30 kHz to 1.3 GHz (0 to 1.0) lin	(± 0.0044 to ±0.022) lin (± 180 to ±1.3) deg	Network analyzer HP8753ES Type-N precision cal kit 85032B APC 7mm precision cal kit HP85031B
300 kHz to 1.3 GHz (0 to 1.0) lin	(± 0.0071 to ±0.035) lin (± 180 to ±2.0) deg	
300 kHz to 1.3 GHz (0 to 1.0) lin	(± 0.0038 to ±0.017) lin (± 180 to ±0.96) deg	Network analyzer HP8753ES Type N precision cal kit 85032B
1.3 GHz to 3 GHz (0 to 1.0) lin	(± 0.0051 to ±0.026) lin (± 180 to ±1.504) deg	
3 GHz to 6 GHz (0 to 1.0) lin	(±0.011 to ±0.050) lin (± 180 to ±3.0) deg	
300 kHz to 1.3 GHz (0 to 1.0) lin	(± 0.0019 to ±0.0072) lin (± 180 to ±0.42) deg	Network analyzer HP8753ES APC 7mm precision cal kit HP85031B
1.3 GHz to 3 GHz (0 to 1.0) lin	(± 0.0036 to ±0.011) lin (± 180 to ±0.59) deg	
3 GHz to 6 GHz (0 to 1.0) lin	(± 0.0057 to ±0.018) lin (± 180 to ±1.1) deg	

Parameter/Range	Best Uncertainty ² (±)	Comments
Transmission S_{12}/ S_{21} – Measure ³ 30 kHz to 1.3 GHz (0 to 20) dB (20 to 40) dB (40 to 60) dB 1.3 GHz to 3 GHz (0 to 20) dB (20 to 40) dB (40 to 60) dB 3 GHz to 6 GHz (0 to 20) dB (20 to 40) dB (40 to 60) dB	(± 0.041 to ± 0.063) dB (± 0.42 to ± 0.46) deg (± 0.063 to ± 0.088) dB (± 0.46 to ± 0.62) deg (± 0.088 to ± 0.29) dB (± 0.62 to ± 2.0) deg (± 0.056 to ± 0.076) dB (± 0.79 to ± 1.3) deg (± 0.076 to ± 0.11) dB (± 1.3 to ± 1.4) deg (± 0.11 to ± 0.32) dB (± 1.4 to ± 2.2) deg (± 0.094 to ± 0.13) dB (± 1.2 to ± 1.6) deg (± 0.13 to ± 0.16) dB (± 1.6 to ± 1.7) deg (± 0.16 to ± 0.51) dB (± 1.7 to ± 3.6) deg	Network analyzer 8753ES Type-N precision cal kit 85032B

⁴ Based on using the standard at the temperature the Fluke 5720A/5725A was calibrated ($\pm 5\text{ }^{\circ}\text{C}$) and assuming the instrument is zeroed at least every seven days or when the ambient temperature changes more than $5\text{ }^{\circ}\text{C}$. For resistance a zero calibration is performed at least every 12 hours within $\pm 1\text{ }^{\circ}\text{C}$ of use. Best measurement uncertainty is based upon 1-year specifications and is read as a portion or percent output plus floor specification. The floor specification is expressed as a fixed value or a portion or percent of the range.

⁵ Based on using the HP 3458A at the temperature ($\pm 5\text{ }^{\circ}\text{C}$) it was calibrated $\pm 5\text{ }^{\circ}\text{C}$ and an auto-calibration (ACAL) was performed within the previous 24 hours ($\pm 1\text{ }^{\circ}\text{C}$ of ambient temperature). Best measurement uncertainty is based upon 1-year specifications and is read as a portion or percent output plus floor specification. The floor specification is expressed as a fixed value or a portion or percent of the range.

⁶ Best Measurement Uncertainty does not include the mismatch.

⁷ Ranges are based upon the system combination used:

Instrument/System	Ranges
HP 8902A	2.5 MHz to 1.3 GHz Range 1 & 2 – SWR 1.18:1 Range 3 – SWR 1.4:1
HP 8902A w/ HP 11722A	2.5 MHz to 1.3 GHz Range 1 & 2 – SWR 1.33:1 Range 3 – SWR 1.5:1
HP 8902A w/ HP 11792A or HP 11793A	(50 to 1300) MHz SWR 1.15:1 (1.3 to 18) GHz SWR 1.25:1 (18 to 26.5) GHz SWR 1.4:1

⁸ Best Uncertainties are based upon the AM depths. For depths between 0 % and 9.99 %, the digit uncertainty (resolution) is 0.01 %. For depths between 10 % and 99.9 % FS, the digit uncertainty (resolution) is 0.1 %.

⁹ Best Uncertainties are based upon the peak phase deviations. For deviations between 0 and 3.999, the digit uncertainty (resolution) is 1 Hz. For deviations between 0 and 39.99, the digit uncertainty (resolution) is 10 Hz. For deviations between 40 and 400, the digit uncertainty (resolution) is 100 Hz.

¹⁰ Standards Laboratory parameters and uncertainties are not available for calibrations in the field.

¹¹ *AM* is the amplitude modulation; *FM* is the frequency modulation; and *TI* is the time interval.