

NO: SAMM 248

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LABORATORY LOCATION:
(PERMANENT LABORATORY)
KEYSIGHT TECHNOLOGIES MALAYSIA SDN. BHD.
BAYAN LEPAS FREE INDUSTRIAL ZONE
11900 PENANG
MALAYSIA

FIELDS OF CALIBRATION:

ELECTRICAL & DIMENSIONAL

This laboratory has demonstrated its technical competence to operate in accordance with MS ISO/IEC 17025:2005 (ISO/IEC 17025:2005).

This laboratory's fulfillment of the requirements of ISO/IEC 17025 means the laboratory meets both the technical competence requirements and management system requirements that are necessary for it to consistently deliver technically valid test results and calibrations. The management system requirements in ISO/IEC 17025 are written in language relevant to laboratory operations and operate generally in accordance with the principles of ISO 9001 (see Joint ISO-ILAC-IAF Communiqué dated April 2017).

* The expanded uncertainties are based on an estimated confidence probability of approximately 95% and have a coverage factor of $k=2$ unless stated otherwise.

- [1] Linear voltage reflection and transmission coefficient measurement
- [2] The CMC is expressed as \pm (of indication in nV/V + floor value in nV)
- [3] iPIMMS is an 'industry' primary impedance measurement service supplied and maintained by UK's National Physical Laboratory.
- [4] The %/% in CMC expresses the uncertainty of measured value (reading in %).
- [5] The CMC is expressed as uncertainty (%/%) of indication (%) + floor value in %.

SCOPE OF CALIBRATION: ELECTRICAL – RF/MICROWAVE (50 Ω SYSTEM)

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
Power Sources Fitted with female Type- N connectors	1 mW at 50 MHz	2.2 μ W	1 mW 50 MHz Reference Source Calibration
Passive Devices Scalar Attenuation, Measure	1.01 kHz to 1 MHz 0 dB to 40 dB 40 dB to 80 dB 80 dB to 110 dB	0.009 dB 0.022 dB 0.033 dB	1 kHz intermediate frequency substitution method
	1 MHz to 80 MHz 0 dB to 40 dB 40 dB to 80 dB 80 dB to 110 dB	0.005 dB 0.010 dB 0.030 dB	

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
Passive Devices Scalar Attenuation, Measure (Continues)	80 MHz to 6 GHz 0 dB to 40 dB 40 dB to 80 dB 80 dB to 110 dB	0.010 dB 0.021 dB 0.032 dB	
Passive Devices Scattering Parameter: Reflection coefficient (linear)	10 kHz to 300 kHz 0 to 0.1 0.1 to 0.5 0.5 to 1.0 300 kHz to 6 GHz 0 to 0.1 0.1 to 0.5 0.5 to 1.0	0.0022 0.0028 0.0055 0.0018 0.0024 0.0052	Measure using 8753ES, 85054B ^[1]
	45 MHz to 50 GHz (See Matrix A)	(See Matrix A)	Measure using E8364B/C
Passive Devices Scattering Parameter: Transmission coefficient	10 kHz to 30 kHz 0 dB to 10 dB 10 dB to 20 dB 20 dB to 30 dB 30 kHz to 6 GHz 0 dB to 10 dB 10 dB to 20 dB 20 dB to 30 dB 30 dB to 40 dB 40 dB to 50 dB 50 dB to 60 dB 60 dB to 70 dB 70 dB to 80 dB	0.062 dB 0.072 dB 0.13 dB 0.057dB 0.060dB 0.061dB 0.073 dB 0.090 dB 0.098 dB 0.15 dB 0.38 dB	Measure using 8753ES, 85054B
	45 MHz to 50 GHz (See Matrix B)	(See Matrix B)	Measure using E8364B/C

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(±)*	Remarks
Calibration Factors	Power Sensor, 100 pW to 1 μW 10 MHz to 50 MHz 50 MHz to 18 GHz 18 GHz to 26.5 GHz 26.5 GHz to 50 GHz 1 μW to 100 μW 9 kHz to 100 kHz 100 kHz to 10 MHz 10 MHz to 50 MHz 50 MHz to 4.2 GHz 4.2 GHz to 18 GHz 18 GHz to 26.5 GHz 26.5 GHz to 50 GHz 100 μW to 10 mW 9 kHz to 100 kHz 100 kHz to 10 MHz 10 MHz to 50 MHz 50 MHz to 4.2 GHz 4.2 GHz to 18 GHz 18 GHz to 26.5 GHz 26.5 GHz to 50 GHz	 0.35 % 0.35 % 1.3 % 1.3 % 0.40 % 0.30 % 0.30 % 0.30 % 0.32 % 1.0 % 1.3 % 0.40 % 0.30 % 0.30 % 0.30 % 0.32 % 1.0 % 1.3 %	Reference to 1 mW at 50 MHz
Power Sensor, Calibration Factors (continue)	10 mW to 100 mW 9 kHz to 100 kHz 100 kHz to 10 MHz 10 MHz to 50 MHz 50 MHz to 4.2 GHz 4.2 GHz to 18 GHz 18 GHz to 26.5 GHz 26.5 GHz to 50 GHz 100 mW to 3 W 100 kHz to 10 MHz 10 MHz to 4.2 GHz 4.2 GHz to 18 GHz	 0.40 % 0.30 % 0.30 % 0.30 % 0.32 % 1.0 % 1.3 % 0.30 % 0.30 % 0.33 %	
75 Ω System	1 μW to 100 mW 100 kHz to 2 GHz	0.97 %	
Frequency Sources	10 MHz	1.3×10^{-11} Hz/Hz	Measure using 5071A, 53132A

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Matrix A

Passive Devices Scattering Parameter: Reflection coefficient (linear)

Frequency	Reflection Coefficient (0 to 1)	
	Uncertainty = $ax^2 + bx + c$ Where x is voltage reflection coefficient in linear	
45 MHz to 2.999 GHz	$0.0029x^2 + 0.0033x + 0.0029$	Using E8364B/C 85054B
3 GHz to 8.999 GHz	$0.0059x^2 + 0.0050x + 0.0053$	
9 GHz to 18 GHz	$0.0132x^2 + 0.0061x + 0.0056$	
45 MHz to 2.999 GHz	$0.0053x^2 + 0.0029x + 0.0026$	Using E8364B/C 85052B
3 GHz to 20.999 GHz	$0.0119x^2 + 0.0045x + 0.0042$	
21 GHz to 26.5 GHz	$0.0138x^2 + 0.0077x + 0.0046$	
45 MHz to 20.999 GHz	$0.0044x^2 + 0.0029x + 0.0052$	Using E8364B/C 85056A
21 GHz to 40.999 GHz	$0.0098x^2 + 0.0083x + 0.0084$	
41 GHz to 50 GHz	$0.0109x^2 + 0.0121x + 0.0106$	

Matrix B

Passive Devices Scattering Parameter: Transmission coefficient

Specific Values	Transmission Coefficient (dB)								
	0 to 10	10 to 20	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80	
45 MHz to 2 GHz	0.022	0.029	0.036	0.046	0.058	0.076	0.102	0.179	Using E8364B/C 85054B
2 GHz to 8 GHz	0.022	0.036	0.044	0.051	0.059	0.076	0.102	0.165	
8 GHz to 18 GHz	0.042	0.055	0.063	0.070	0.078	0.094	0.116	0.165	
45 MHz to 2 GHz	0.020	0.027	0.035	0.045	0.056	0.074	0.100	0.177	Using E8364B/C 85052B
2 GHz to 8 GHz	0.020	0.034	0.042	0.049	0.057	0.074	0.100	0.169	
8 GHz to 18 GHz	0.047	0.060	0.068	0.075	0.083	0.099	0.120	0.169	
18 GHz to 26.5 GHz	0.074	0.087	0.095	0.102	0.110	0.126	0.145	0.180	
45 MHz to 2 GHz	0.022	0.029	0.036	0.046	0.058	0.076	0.102	0.178	Using E8364B/C 85056A
2 GHz to 18 GHz	0.022	0.036	0.043	0.051	0.059	0.076	0.102	0.156	
18 GHz to 26.5 GHz	0.048	0.061	0.069	0.076	0.085	0.100	0.120	0.156	
26.5 GHz to 50 GHz	0.086	0.110	0.119	0.126	0.135	0.151	0.173	0.228	

Signatories:

1. Yong En Haur
2. Kee Kah Ghim

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(±)*	Remarks
Scattering Parameter: Reflection Coefficient, Γ	$-1 \leq \text{Re}\{\Gamma\} \leq 1$ $-1 \leq \text{Im}\{\Gamma\} \leq 1$ constrained by: $0 \leq \Gamma \leq 1$		Measure using iPIMMS ^[2]
Passive Devices fitted with Type-N connectors	45 MHz to 18 GHz	0.0030 ^[1]	
Passive Devices fitted 3.5 mm connectors	45 MHz to 33 GHz	0.0040 ^[1]	
Scattering Parameter: Transmission Coefficient, T	$-1 \leq \text{Re}\{T\} \leq 1$ $-1 \leq \text{Im}\{T\} \leq 1$ constrained by: $0 \leq T \leq 1$		Measure using iPIMMS ^[2]
Passive Devices fitted with Type-N connectors	45 MHz to 18 GHz 0 dB to 10 dB 10 dB to 20 dB 20 dB to 30 dB 30 dB to 40 dB 40 dB to 50 dB 50 dB to 60 dB 60 dB to 70 dB 70 dB to 80 dB 80 dB to 90 dB 90 dB to 100 dB	0.0002 dB 0.0088 dB 0.018 dB 0.027 dB 0.037 dB 0.056 dB 0.12 dB 0.34 dB 1.0 dB 2.9 dB	
Passive Devices fitted 3.5 mm connectors	45 MHz to 33 GHz 0 dB to 10 dB 10 dB to 20 dB 20 dB to 30 dB 30 dB to 40 dB 40 dB to 50 dB 50 dB to 60 dB 60 dB to 70 dB 70 dB to 80 dB 80 dB to 90 dB 90 dB to 100 dB	0.0002 dB 0.0088 dB 0.018 dB 0.027 dB 0.037 dB 0.056 dB 0.12 dB 0.34 dB 1.0 dB 2.9 dB	

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FOR SIGNAL SOURCE**

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(±)*	Remarks
Signal Sources -Absolute RF Power in Coaxial	(See Matrix C)	(See Matrix C)	Power Sensor Power Meter (See Matrix C)
Signal Sources - RF Power Flatness in Coaxial Line	(See Matrix D)	(See Matrix D)	Power Sensor Power Meter (See Matrix D)
Signal Sources - Harmonic Content	Fundamental Frequency 1 MHz to 25 GHz 0 to 10 dBm Harmonic Frequency 2 MHz to 50 GHz -110 dBm to 0 dBm	0.51 dB	E4448A
Signal Sources - Pulse Time Parameters Rise/Fall Time	0 to 10 dBm 10 MHz to 50 GHz	86 ps	86100C 86117A

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks	
Signal Sources – Modulation Frequency Modulation Peak Frequency Deviation	-18 to 30 dBm		E4448A	
			0.015 Hz/Hz	f_c = Carrier Frequency f_m = Modulation Rate Δf =Peak Deviation $\beta = \Delta f / f_m$
			0.010 Hz/Hz	
			0.015 Hz/Hz	
			0.010 Hz/Hz	
			0.025 Hz/Hz	
			0.010 Hz/Hz	
			0.038 Hz/Hz	
			0.010 Hz/Hz	
0.085 Hz/Hz				

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
Signal Sources – Modulation Frequency Modulation Peak Frequency Deviation (continue)	f_c : 31.15 GHz to 50 GHz f_m : 50 Hz to 200 kHz Δf : 250 Hz to 400 kHz $\beta > 32$	0.010 Hz/Hz	E4448A f_c = Carrier Frequency f_m = Modulation Rate Δf =Peak Deviation $\beta = \Delta f / f_m$
Amplitude Modulation Depth	-18 to 30 dBm f_m: 50 Hz to 100 kHz f_c : 100 kHz to 10 MHz Depth: 5 % to 99 % f_c : 10 MHz to 3 GHz Depth: 20 % to 99 % f_c : 10 MHz to 3 GHz Depth: 5 % to 20 % f_c : 3 GHz to 26.5 GHz Depth: 20 % to 99 % f_c : 3 GHz to 26.5 GHz Depth: 5 % to 20 % f_c : 26.5 GHz to 31.15 GHz Depth: 20 % to 99 % f_c : 26.5 GHz to 31.15 GHz Depth: 5 % to 20 % f_c : 31.15 GHz to 50 GHz Depth: 5 % to 20 % f_c : 31.15 GHz to 50 GHz Depth: 5 % to 20 %	 0.0075 %/° ^[4] 0.005 %/° ^[4] 0.025 %/° ^[4] 0.015 %/° ^[4] 0.045 %/° ^[4] 0.019 %/° ^[4] 0.068 %/° ^[4] 0.06 %/° ^[4] 0.26 %/° ^[4]	 E4448A f_c = Carrier Frequency f_m = Modulation Rate

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
Phase Modulation	-18 to 30 dBm		E4448A f_c = Carrier Frequency $\Delta\Phi$ = Phase Deviation
Peak phase deviation	f_c : 100 kHz to 6.6 GHz $\Delta\Phi > 0.7$ rad	0.01 rad/rad	
	f_c : 100 kHz to 6.6 GHz $\Delta\Phi > 0.3$ rad	0.03 rad/rad	
	f_c : 6.6 GHz to 13.2 GHz $\Delta\Phi > 2.0$ rad	0.01 rad/rad	
	f_c : 6.6 GHz to 13.2 GHz $\Delta\Phi > 0.6$ rad	0.03 rad/rad	
	f_c : 13.2 GHz to 26.5 GHz $\Delta\Phi > 4.0$ rad	0.01 rad/rad	
	f_c : 13.2 GHz to 26.5 GHz $\Delta\Phi > 1.2$ rad	0.03 rad/rad	
	f_c : 26.5 GHz to 31.15 GHz $\Delta\Phi > 4.0$ rad	0.01 rad/rad	
	f_c : 26.5 GHz to 31.15 GHz $\Delta\Phi > 1.3$ rad	0.03 rad/rad	
	f_c : 31.15 GHz to 50 GHz $\Delta\Phi > 8$ rad	0.01 rad/rad	
	f_c : 31.15 GHz to 50 GHz $\Delta\Phi > 2.4$ rad	0.03 rad/rad	
Modulation Rate	$100 \text{ kHz} \leq f_c < 50 \text{ GHz}$		E4448A $\beta = \Delta f / f_m$ f_m = Modulation Rate
Amplitude Modulation Rate	Depth $\geq 20\%$ $f_m \leq 100 \text{ kHz}$	0.062 Hz	
Frequency Modulation Rate	$\beta \geq 0.01$ $f_m \leq 200 \text{ kHz}$	0.062 Hz	
Phase Modulation Rate	$\beta \geq 0.01$ $f_m \leq 20 \text{ kHz}$	0.062 Hz	

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
Signal Sources - Modulation Distortion	0.01% to 100%		E4448A f_c =Carrier Frequency f_m = Modulation Rate
Amplitude Modulation Distortion	f_m : 20 Hz to 1 kHz f_c : 0.1 to 10 MHz Depth: > 1 % Depth: > 3 %	0.0012 %/ % + 0.8 % ^[5] 0.0012 %/ % + 0.3 % ^[5]	
	f_m : 20 Hz to 1 kHz f_c : 10 MHz to 26.5 GHz Depth: > 1 % Depth: > 3 %	0.0012 %/ % + 1.0 % ^[5] 0.0012 %/ % + 0.4 % ^[5]	
	f_m : 20 Hz to 1 kHz f_c : 26.5 to 50 GHz Depth: > 1 % Depth: > 3 % Depth: > 5 %	0.0012 %/ % + 6.2 % ^[5] 0.0012 %/ % + 2.0 % ^[5] 0.0012 %/ % + 1.5 % ^[5]	
Phase Modulation Distortion	f_c : 1 MHz to 6.6 GHz f_m : 20 Hz to 500 Hz $\Delta\Phi > 0.8$ rad $\Delta\Phi \geq 2.5$ rad	0.0012 %/ % + 0.3 % ^[5] 0.0012 %/ % + 0.1 % ^[5]	
	f_c : 1 MHz to 6.6 GHz f_m : 500 Hz to 1 kHz $\Delta\Phi > 0.4$ rad $\Delta\Phi \geq 1.0$ rad	0.0012 %/ % + 0.3 % ^[5] 0.0012 %/ % + 0.1 % ^[5]	
	f_c : 6.6 GHz to 13.2 GHz f_m : 20 Hz to 500 Hz $\Delta\Phi > 1.8$ rad $\Delta\Phi \geq 5.5$ rad	0.0012 %/ % + 0.3 % ^[5] 0.0012 %/ % + 0.1 % ^[5]	
	f_c : 6.6 GHz to 13.2 GHz f_m : 500 Hz to 1 kHz $\Delta\Phi > 0.8$ rad $\Delta\Phi \geq 2.5$ rad	0.0012 %/ % + 0.3 % ^[5] 0.0012 %/ % + 0.1 % ^[5]	
	f_c : 13.2 GHz to 31.15 GHz f_m : 20 Hz to 500 Hz $\Delta\Phi > 3.5$ rad $\Delta\Phi \geq 10.0$ rad	0.0012 %/ % + 0.3 % ^[5] 0.0012 %/ % + 0.1 % ^[5]	
	f_c : 13.2 GHz to 31.15 GHz f_m : 500 Hz to 1 kHz $\Delta\Phi > 1.2$ rad $\Delta\Phi \geq 4.0$ rad	0.0012 %/ % + 0.3 % ^[5] 0.0012 %/ % + 0.1 % ^[5]	

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
Signal Sources - Modulation Distortion (continue) Phase Modulation Distortion Frequency Modulation Distortion	f_c : 31.15 GHz to 50 GHz f_m : 20 Hz to 500 Hz $\Delta\Phi > 7.5$ rad $\Delta\Phi \geq 19.0$ rad f_c : 31.15 GHz to 50 GHz f_m : 500 Hz to 1 kHz $\Delta\Phi > 3.0$ rad $\Delta\Phi \geq 8.0$ rad f_c : 1 MHz to 6.6 GHz f_m : 20 Hz to 1 kHz Δf : 500 Hz to 2 kHz $\Delta f \geq 2.0$ kHz f_c : 6.6 GHz to 13.2 GHz f_m : 20 Hz to 1 kHz $\Delta f > 2.3$ kHz $\Delta f \geq 4.5$ kHz f_c : 13.2 GHz to 31.15 GHz f_m : 20 Hz to 1 kHz $\Delta f > 2.7$ kHz $\Delta f \geq 6.0$ kHz f_c : 31.15 GHz to 50 GHz f_m : 20 Hz to 1 kHz $\Delta f > 4.0$ kHz $\Delta f \geq 12.0$ kHz	0.0012 %/ % + 0.3 % ^[5] 0.0012 %/ % + 0.1 % ^[5] 0.0012 %/ % + 0.3 % ^[5] 0.0012 %/ % + 0.1 % ^[5] 0.0012 %/ % + 0.3 % ^[5] 0.0012 %/ % + 0.1 % ^[5] 0.0012 %/ % + 0.3 % ^[5] 0.0012 %/ % + 0.1 % ^[5] 0.0012 %/ % + 0.3 % ^[5] 0.0012 %/ % + 0.1 % ^[5]	E4448A f_c =Carrier Frequency f_m = Modulation Rate
Signal Sources -Digital Modulation Carrier: 2 MHz to 2.65 GHz Error Vector Magnitude for Modulation Types: MSK, GMSK, BPSK, DQPSK, $\pi/4$ DQPSK, 8PSK, 16QAM and 32QAM, QPSK Phase Error for Modulation Types: MSK, GMSK, BPSK, DQPSK, $n/4$ DQPSK, 8PSK, 16QAM and 32QAM, QPSK Error Vector Magnitude for FSK Modulation	Mod Frequency Span: (1 to 100) kHz (0.1 to 1) MHz 1 MHz to 2.65 GHz (1 to 100) kHz (0.1 to 1) MHz 1 MHz to 2.65 GHz Mod Frequency: 3.2 kHz 1.152 kHz	0.31 % rms 0.51 % rms 1.1 % rms 0.18 ° rms 0.35 ° rms 0.58 ° rms 0.51 % rms 1.60 % rms	89441A

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
Signal Sources -Phase Noise	Power level: 0dBm to 15dBm f _c : 50 kHz-1600 MHz f offset: 0.1 Hz to 1 MHz	2.4 dBc/Hz	N5500A
	Power level: 0dBm to 15dBm f _c : 1.2 to 26.5 GHz f offset: 0.1 Hz to 1 MHz	2.4 dBc/Hz	
Signal Sources – Frequency	100 MHz to 45 GHz	9.6×10^{-12} Hz/Hz	E4448A, 5071A

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Matrix C

Signal Sources -Absolute RF Power in 50 Ω Coaxial Line

Frequency	RF Power Level (Uncertainty in mW/W unless stated otherwise)			Power Sensor/ Spectrum Analyzer
9 kHz to 6 GHz	10 nW to 100 nW	100 nW to 100 mW		E9304A
	34 to 99	23 to 35		
9 kHz to 18 GHz	10 nW to 100 nW	100 nW to 1 W		E9304A H19
	0.98 nW to 3.7 nW	24 to 37		
10 MHz to 18 GHz	10 nW to 1 mW	1 mW to 1 W		E9300 H25
	37 to 48	32 to 42		
50 MHz to 35 GHz	1 μ W to 10 μ W	10 μ W to 10 mW	10 mW to 100 mW	8487A
	0.13 μ W to 0.26 μ W	9 to 26	32 to 39	
	0.14 μ W to 0.40 μ W	14 to 40	35 to 50	
	0.14 μ W to 0.61 μ W	31 to 61	45 to 69	
9 kHz to 20 GHz	1 fW to 10 fW	10 fW to 3.2 μ W		E9304A, 8487A, E4448A
	8 to 20	11 to 22		
20 GHz to 50 GHz	19 to 64	14 to 64		
50 MHz to 20 GHz	500 pW to 10 nW	10 nW to 10 μ W		8487D
	0.056 nW to 0.26 nW	14 to 34		
20 GHz to 50 GHz	0.062 nW to 1.1 nW	57 to 120		
10 MHz to 20 GHz	10 μ W to 100 mW			N8488A
	10 to 22			
	35 to 53			
	70 to 74			
97 to 130				
50 GHz to 67 GHz	10 μ W to 100 mW			V8486A
	28 to 76			

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Matrix D

Signal Sources - RF Power Flatness in 50 Ω Coaxial Line

Frequency	RF Power Level (Uncertainty in mW/W unless stated otherwise)		Power Sensor
9 kHz to 6 GHz	10 nW to 2.2 mW	2.2 mW to 100 mW	E9304A
	0.58 nW to 1.4 nW	5 to 12	
9 kHz to 18 GHz	10 nW to 100 nW	100 nW to 1 W	E9304A H19
	0.59 nW to 1.3 nW	10 to 13	
10 MHz to 18 GHz	10 nW to 1 mW	1 mW to 1 W	E9300 H25
	9 to 18	9 to 17	
50 MHz to 35 GHz	1 μ W to 10 μ W	10 μ W to 100 mW	8487A
	0.059 nW to 0.22 μ W	5 to 22	
35 GHz to 45 GHz	0.064 μ W to 0.38 μ W	18 to 38	
45 GHz to 50 GHz	0.07 μ W to 0.59 μ W	31 to 60	
50 MHz to 20 GHz	500 pW to 10 nW	10 nW to 10 μ W	8487D
	12 to 58	11 to 24	
20 GHz to 50 GHz	56 to 120	56 to 110	
10 MHz to 20 GHz	10 μ W to 100 mW		N8488A
	7 to 51		
	34 to 51		
	69 to 72		
96 to 130			
50 GHz to 67 GHz	10 μ W to 100 mW		V8486A
	13 to 37		

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Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
Signal Analyzers – Absolute RF Power in Coaxial Line	(See Matrix E)	(See Matrix E)	Signal Sources, Power Splitters, Power Meters, Power Sensors (See Matrix E)
Signal Analyzers – Relative RF Power in Coaxial Line	0 dB to 70 dB 70 dB to 110 dB Max power level: 10 dBm 50 MHz to 2 GHz	0.013 dB 0.040 dB	E8257D, Step Attenuators
Signal Analyzers, Frequency Counters – Frequency	100 MHz to 50 GHz	1.4×10^{-11} Hz/Hz	E8257D, 5071A
Signal Analyzers – Phase Noise	Carrier frequency: 1 GHz Offset frequency: 100 Hz to 10 MHz	0.36 dB	Signal Source 500-13438 Source phase noise: -107 to -167 dBc/Hz

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Matrix E

Signal Analyzers –Absolute RF Power in 50 Ω Coaxial Line

Frequency	RF Power Level (Uncertainty in mW/W unless stated otherwise)			Power Sensor
	1 nW to 10 nW	10 nW to 1 μ W	1 μ W to 10 μ W	
10 MHz to 18 GHz	0.14 nW to 0.17 nW	15 to 19	20 to 23	8481D
	0.14 nW to 0.22 nW	18 to 27	39 to 44	
50 MHz to 26.5 GHz	0.14 nW to 0.20 nW	15 to 37	38 to 51	8487D
30 GHz to 50 GHz	0.44 nW to 0.21 nW	42 to 160	54 to 170	
75 Ω Type N 100 kHz to 3 GHz	0.33 μ W to 1.4 μ W	14 to 30	14 to 30	8483A
	0.34 μ W to 0.97 μ W	10 to 20	32 to 37	8482A
10 MHz to 18 GHz	0.33 μ W to 1 μ W	10 to 17	32 to 37	8481A
50 MHz to 26.5 GHz	0.34 μ W to 1.7 μ W	17 to 26	35 to 42	8485A
50 MHz to 45 GHz	0.34 μ W to 1.6 μ W	16 to 51	16 to 47	8487A
45 GHz to 50 GHz	0.36 μ W to 4.5 μ W	44 to 120	45 to 110	
10 MHz to 67 GHz	10 μ W to 2 mW			N8488A
	32 to 110			

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**SCOPE OF CALIBRATION: ELECTRICAL – RF & MICROWAVE (50 Ω SYSTEM)
FOR SIGNAL SOURCE**

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(±)*	Remarks
CISPR 16-1 Detectors (Response of Quasi-peak, peak, average, RMS) at 50 Ω system Pulse Spectral Density	13.50 μVs 1.350 μVs Band A (9 to 150) kHz PRF ¹ : 25 Hz 0.3160 μVs 0.0316 μVs Band B (0.15 to 30) MHz PRF ¹ : 100 Hz 0.0440 μVs Band C,D (30 to 480) MHz Band C,D (500 to 1000) MHz PRF ¹ : 100 Hz 0.0044 μVs Band C,D (30 to 480) MHz Band C,D (500 to 1000) MHz PRF ¹ : 100 Hz	0.27 dB 0.26 dB 0.26 dB 0.26 dB 0.28 dB 0.33 dB 0.27 dB 0.32 dB	IGUU 2916 PRF ¹ = pulse repetitive frequency
CISPR 16-1-1 Detectors (Response of Quasi-peak, peak, average, RMS) at 50 Ω system Sine Wave Pulse Spectral Density relative to PRF¹	60 dBμV 100 kHz, 1 MHz, 10 MHz, 100 MHz Pulse Level²: 60 dBμV PRF ¹ : (0.1 to 200) Hz Band A relative to 25 Hz B,C,D relative to 100 Hz Pulse Level²: 40 dBμV PRF ¹ : 0.1 Hz to 20 kHz Band A relative to 25 Hz B,C,D relative to 100 Hz	0.16 dB 0.11 dB 0.11dB	IGUU 2916 Note 2: Pulse level for CISPR weighting quasi-peak

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Signatories:

1. Yong En Haur
2. Kok Jian Ling

NO: SAMM 248

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SCOPE OF CALIBRATION: ELECTRICAL – DC & LOW FREQUENCY

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
DC Sources, DC Voltmeters	150 μ V to 10 V	5 nV/V + 100 nV ^[2]	Josephson Voltage Standard
DC Resistance Sources Specific Values	0.1 Ω 0.48 Ω 1 Ω 4.8 Ω 10 Ω 65 Ω 100 Ω 1 k Ω 10 k Ω 100 k Ω 1 M Ω 10 M Ω 100 M Ω	0.13 $\mu\Omega$ 0.61 $\mu\Omega$ 1.3 $\mu\Omega$ 6.7 $\mu\Omega$ 13 $\mu\Omega$ 87 $\mu\Omega$ 0.13 m Ω 1.3 m Ω 13 m Ω 0.13 Ω 1.6 Ω 21 Ω 0.23 k Ω	Measure using resistance standards and bridge
DC Voltage Sources Voltage Range	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1000) V	240 nV 740 nV 8.5 μ V 74 μ V 1.1 mV	Measure using 732B, voltmeter, voltage divider
DC Current Sources Current Range	(0 to 100) μ A (100 to 300) μ A 300 μ A to 1 mA (1 to 3) mA (3 to 10) mA (10 to 30) mA (30 to 100) mA (100 to 300) mA 300 mA to 1 A (1 to 15) A (15 to 100) A (100 to 200) A (200 to 220) A	380 pA 810 pA 3.4 nA 7.3 nA 37 nA 85 nA 620 nA 970 nA 5.9 μ A 82 μ A/A + 3 μ A 76 μ A/A + 66 μ A 150 μ A/A + 570 μ A 21 μ A/A + 64 μ A	Measure using resistance standards and voltmeter Measure using current shunt 9230
AC Voltage Sources Voltage Range	1 mV to 1000 V (See Matrix F)	(See Matrix F)	Measure using 5790A
AC Current Sources Current Range	10 μ A to 1 A (See Matrix G)	(See Matrix G)	Measure using 5790A with ac current shunts
Time Interval Sources Interval Range	0.8 ns to 20 ns 20 ns to 10 μ s 10 μ s to 1 ms 1 ms to 1 s 1 s to 10 s	1 ms/s + 9.0 ps 30 ps/s + 1 ns 20 ps/s + 1 ns 10 ps/s + 1 ns 5 ps/s + 1 ns	Measure using scope 86100C and counter 53132A

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Matrix F

AC Voltage Sources

Voltage Range	Frequency Range (kHz)							
	0.01 to 0.02	0.02 to 0.04	0.04 to 20	20 to 50	50 to 100	100 to 300	300 to 500	500 to 1000
	Uncertainty = $u_1 \times \mu\text{V/V} + u_2 \mu\text{V}$ <i>x</i> is voltage in V							
600 μV to 2 mV	-	-	68x + 1.0	200x + 1.5	190x + 1.9	1100x + 2.7	1600x + 5.7	3900x + 5.4
(2 to 6) mV	73x + 1.0	27x + 1.4	35x + 1.0	75x + 1.4	98x + 1.9	210x + 2.9	620x + 5.8	2200x + 5.5
(6 to 20) mV	64x + 1.1	40x + 0.97	37x + 0.97	140x + 1.1	140x + 1.6	260x + 2.4	500x + 5.4	1400x + 5.6
(20 to 60) mV	64x + 1.1	36x + 1.1	36x + 0.99	77x + 1.1	82x + 1.5	160x + 2.5	350x + 5.1	930x + 5.3
(60 to 200) mV	61x + 0.98	34x + 0.93	29x + 0.92	29x + 1.3	82x + 1.2	150x + 2.3	320x + 4.9	840x + 5.6
(200 to 600) mV	-	-	24x + 1.3	-	-	-	-	-
600 mV to 2 V	50x + 0.38	26x + 0.34	19x + 0.22	21x + 0.14	40x + 0.19	88x + 0.77	180x + 3.0	690x + 2.9
(2 to 6) V	-	-	22x + 2.5	-	40x + 0.19	-	-	-
(6 to 20) V	49x + 10	27x + 11	17x + 33	21x + 33	48x + 79	120x + 3.7	300x + 14	930x + 0.69
(20 to 60) V	50x + 26	27x + 110	21x + 17	23x + 22	53x + 61	-	-	-
(60 to 200) V	50x + 73	27x + 260	22x + 310	27x + 700	53x + 840	-	-	-
(200 to 400) V	-	-	18x + 3800	85x + 1200	-	-	-	-
(400 to 600) V	-	-	-	88x + 71	390x + 540	-	-	-
(600 to 700) V	-	25x + 550	89x + 330	-	-	-	-	-
(700 to 1000) V	-	34x + 370	30x + 440	-	-	-	-	-

Matrix G

AC Current Sources

Current Range	Frequency (kHz)				
	0.01 to 0.02	0.02 to 0.045	0.045 to 0.1	0.1 to 5	5 to 10
(0 to 10) μA	2.3 nA	2.3 nA	2.1 nA	2.3 nA	2.3 nA
(10 to 100) μA	18 nA	17 nA	17 nA	16 nA	18 nA
100 μA to 1 mA	150 nA	150 nA	140 nA	140 nA	150 nA
(1 to 10) mA	1.4 μA	1.4 μA	1.3 μA	1.3 μA	1.4 μA
(10 to 100) mA	14 μA	14 μA	13 μA	13 μA	14 μA
100 mA to 1 A	180 μA	170 μA	170 μA	160 μA	180 μA

Signatories:

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2. Neng Siang Yen

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SCOPE OF CALIBRATION: ELECTRICAL – DC & LOW FREQUENCY

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
DC Voltage Meters Voltage Range	(0 to 0.1) V (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1000) V	95 nV 770 nV 2.2 μ V 110 μ V 5.8 mV	Generate using 5720A with 3458A
Resistance Meters Fixed Value	1 Ω 10 Ω 100 Ω 1 k Ω 10 k Ω 100 k Ω 1 M Ω 10 M Ω 100 M Ω 1 G Ω	4.7 $\mu\Omega$ 15 $\mu\Omega$ 130 $\mu\Omega$ 1.5 m Ω 5.2 m Ω 180 m Ω 2.2 Ω 78 Ω 7.9 k Ω 210 k Ω	Generate using 5720A or fixed resistance with 3458A
DC Current Meters Current Range	(0 to 100) nA (0.1 to 1) μ A (1 to 10) μ A (10 to 100) μ A 100 μ A to 1 mA (1 to 10) mA (10 to 100) mA 100 mA to 1 A	3.7 pA 4.2 pA 43 pA 350 pA 2.8 nA 30 nA 560 nA 43 μ A	Generate using 5720A with 3458A
AC Voltage Meters Voltage Range	10 mV to 1000 V (See Matrix H)	(See Matrix H)	Generate using 5720A, 3325B with 3458A
AC Current Meters Current Range	(0 to 10) μ A 45 Hz to 1 kHz (10 to 100) μ A 45 Hz to 1 kHz 100 μ A to 1 mA 45 Hz to 1 kHz (1 to 10) mA 45 Hz to 1 kHz (10 to 100) mA 45 Hz to 1 kHz 100 mA to 1 A 45 Hz to 1 kHz	4.7 nA 11 nA 110 nA 1.1 μ A 11 μ A 120 μ A	Generate using 5720A with 3458A
Frequency Meters Specific Values	1 Hz 10 MHz	20 μ Hz 58 Hz	Generate using 3325B

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 Matrix H
 AC Voltage Meters

Voltage Range	Frequency (kHz)					
	0.001 to 0.04	0.04 to 1	1 to 20	20 to 50	50 to 100	100 to 300
(0 to 10) mV	-	-	350 nV	330 nV	-	560 nV
(10 to 100) mV	-	-	3 μ V	2.8 μ V	-	5.1 μ V
100 mV to 1 V	-	15 μ V	13 μ V	16 μ V	26 μ V	51 μ V
(1 to 10) V	140 μ V	140 μ V	100 μ V	260 μ V	1.4 mV	560 μ V
(10 to 100) V	-	2.4 mV	2.1 mV	2.0 mV	1.9 mV	-
(100 to 750) V	-	13.0 mV	81 mV	-	-	-

Voltage Range	Frequency (MHz)				
	0.3 to 1	1 to 2	2 to 4	4 to 8	8 to 10
(0 to 10) mV	1.2 μ V	7.1 μ V	52 μ V	-	-
(10 to 100) mV	11 μ V	77 μ V	520 μ V	990 μ V	1.2 mV
100 mV to 1 V	74 μ V	-	5.2 mV	9.9 mV	6.2 mV
(1 to 3) V	-	15 mV	16 mV	30 mV	37 mV
(1 to 10) V	2.3 mV	-	-	-	-

Signatories:

1. Lau Chee Keong
2. Yong En Haur
3. Neng Siang Yen

NO: SAMM 248

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SCOPE OF CALIBRATION: ELECTRICAL – 4T CAPACITANCE METER

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
4T Capacitance meter	1 pF		Measure using 16380A /16380C
	(20 to 100) Hz	15 fF	
	100 Hz to 1 kHz	0.84 fF	
	1 kHz	0.12 fF	
	1 kHz to 1 MHz	0.56 fF	
	1 MHz	0.14 fF	
	(1 to 2) MHz	0.58 fF	
	2 MHz	0.25 fF	
	10 pF		
	(20 to 100) Hz	19 fF	
	100 Hz to 1 kHz	1.1 fF	
	1 kHz	0.91 fF	
	1 kHz to 1 MHz	0.91 fF	
	1 MHz	0.91 fF	
	(1 to 2) MHz	0.93 fF	
	2 MHz	0.93 fF	
	100 pF		
	(20 to 100) Hz	19 fF	
	100 Hz to 1 kHz	10 fF	
	1 kHz	10 fF	
	1 kHz to 1 MHz	12 fF	
	1 MHz	12 fF	
	(1 to 2) MHz	12 fF	
	2 MHz	12 fF	
	1000 pF		
	(20 to 100) Hz	0.64 pF	
	100 Hz to 1 kHz	0.64 pF	
	1 kHz	0.11 pF	
	1 kHz to 1 MHz	0.64 pF	
	1 MHz	0.12 pF	
	(1 to 2) MHz	0.65 pF	
	2 MHz	0.18 pF	

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SCOPE OF CALIBRATION: ELECTRICAL – 4T CAPACITANCE METER

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
4T Capacitance meter	10 nF		Measure using 16380A /16380C
	(20 to 120) Hz	0.63 pF	
	120 Hz	0.63 pF	
	1 kHz	3.20 pF	
	10 kHz	0.53 pF	
	100 kHz	35 pF	
	100 nF		
	(20 to 120) Hz	4.4 pF	
	120 Hz	4.4 pF	
	1 kHz	4.4 pF	
	10 kHz	4.8 pF	
	100 kHz	5.1 pF	
	1 μF		
	(20 to 120) Hz	2.4 nF	
	120 Hz	55 pF	
	1 kHz	47 pF	
	10 kHz	47 pF	
	100 kHz	89 pF	
	10 μF		
	(20 to 120) Hz	4.1 nF	
120 Hz	0.77 nF		
1 kHz	0.78 nF		
10 kHz	1.8 nF		
100 kHz	8.4 nF		

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SCOPE OF CALIBRATION: ELECTRICAL – 4T CAPACITANCE METER

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
4T Dissipation meter	1 pF		Measure using 16380A /16380C
	(20 to 100) Hz	9.5E-03	
	100 Hz to 1 kHz	9.2E-04	
	1 kHz	2.1E-05	
	1 kHz to 1 MHz	3.1E-05	
	1 MHz	3.1E-05	
	(1 to 2) MHz	6.1E-05	
	2 MHz	6.1E-05	
	10 pF		
	(20 to 100) Hz	1.3E-03	
	100 Hz to 1 kHz	8.7E-05	
	1 kHz	2.1E-05	
	1 kHz to 1 MHz	2.1E-05	
	1 MHz	2.1E-05	
	(1 to 2) MHz	2.1E-05	
	2 MHz	2.1E-05	
	100 pF		
	(20 to 100) Hz	1.6E-04	
	100 Hz to 1 kHz	2.1E-05	
	1 kHz	2.1E-05	
	1 kHz to 1 MHz	2.1E-05	
	1 MHz	2.1E-05	
	(1 to 2) MHz	2.1E-05	
	2 MHz	2.1E-05	
	1000 pF		
	(20 to 100) Hz	1.9E-04	
	100 Hz to 1 kHz	2.1E-05	
	1 kHz	2.1E-05	
1 kHz to 1 MHz	3.1E-05		
1 MHz	3.1E-05		
(1 to 2) MHz	6.1E-05		
2 MHz	6.1E-05		

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SCOPE OF CALIBRATION: ELECTRICAL – 4T CAPACITANCE METER

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
4T Dissipation meter	10 nF (20 to 120) Hz	2.1E-05	Measure using 16380A /16380C
	120 Hz	2.1E-05	
	1 kHz	2.6E-05	
	10 kHz	2.1E-05	
	100 kHz	2.2E-05	
	100 nF (20 to 120) Hz	3.4E-05	
	120 Hz	3.4E-05	
	1 kHz	2.1E-05	
	10 kHz	4.8E-05	
	100 kHz	4.6E-05	
	1 μF (20 to 120) Hz	4.3E-05	
	120 Hz	4.3E-05	
	1 kHz	2.1E-05	
	10 kHz	3.1E-05	
	100 kHz	3.7E-04	
	10 μF (20 to 120) Hz	4.6E-05	
	120 Hz	4.6E-05	
	1 kHz	3.1E-05	
	10 kHz	2.9E-04	
	100 kHz	7.4E-04	

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SCOPE OF CALIBRATION: ELECTRICAL – 4T CAPACITANCE METER

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
4T AC Resistance meter	10 Ω		Measure using 42030A
	(20 to 100) Hz	4.3 m Ω	
	100 Hz to 1 MHz	4.5 m Ω	
	1 MHz	3.3 m Ω	
	(1 to 2) MHz	6.0 m Ω	
	2 MHz	5.2 m Ω	
	100 Ω		
	(20 to 100) Hz	51 m Ω	
	100 Hz to 1 MHz	51 m Ω	
	1 MHz	31 m Ω	
	(1 to 2) MHz	57 m Ω	
	2 MHz	41 m Ω	
	1 kΩ		
	(20 to 100) Hz	0.39 Ω	
	100 Hz to 1 MHz	0.39 Ω	
	100 kHz	0.31 Ω	
	1 MHz	0.31 Ω	
	(1 to 2) MHz	0.39 Ω	
	2 MHz	0.31 Ω	
	10 kΩ		
	(20 to 100) Hz	2.3 Ω	
	100 kHz to 1 MHz	3.2 Ω	
	100 kHz	2.1 Ω	
	1 MHz	3.1 Ω	
100 kΩ			
(20 to 100) Hz	26 Ω		
100 kHz to 1 MHz	25 Ω		
100 kHz	28 Ω		
1 MHz	6.6 Ω		

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Signatories:

1. Kok Jian Ling
2. Yong En Haur
3. Neng Siang Yen

NO: SAMM 248

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SCOPE OF CALIBRATION: DIMENSIONAL

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
Plain Plug Gages	0.5 mm to 12 mm	0.67 μ m	Measure using Supermicrometer with laser interferometer and master cylinder gauge
Thread plug gages Pitch Diameter (metric threads, 0.2 – 6 mm pitch)	1.0 mm to 15 mm	1.7 μ m	Measure using Supermicrometer with laser interferometer, master cylinder gauge and thread wire gauge.
External micrometer (digital & analog)	0 mm to 25 mm	1.7 μ m	Measure using Block Gauge Set

Signatories:

1. **Khoo Teng Kok**
2. **Ng Wei Lih**

NO: SAMM 248

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SCOPE OF CALIBRATION: ELECTRICAL – DC & LOW FREQUENCY

SITE: CATEGORY I

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
DC Voltmeter	(0 to 220) mV (0.22 to 2.2) V (2.2 to 11) V (11 to 22) V (22 to 220) V (220 to 1100) V	7.5 μ V/V + 0.4 μ V 5.0 μ V/V + 0.7 μ V 3.5 μ V/V + 2.5 μ V 3.5 μ V/V + 4 μ V 5.0 μ V/V + 40 μ V 6.5 μ V/V + 400 μ V	Fluke 5720A
DC Voltmeter Fixed Value	0 V 0.1 V -0.1 V 1 V -1 V 10 V -10 V 100 V -100 V 1000 V -1000 V	14 nV 0.79 μ V 0.79 μ V 3.1 μ V 3.1 μ V 6.5 μ V 28 μ V 0.50 mV 0.50 mV 6.9 mV 6.9 mV	Golden DMM 3458A and Fluke 5720A
DC Current Meter	(0 to 220) μ A (0.22 to 2.2) mA (2.2 to 22) mA (22 to 100) mA (100 to 220) mA (0.22 to 1) A (1 to 2.2) A (2.2 to 5) A (5 to 10) A	40 μ A/A + 6 nA 35 μ A/A + 7 nA 35 μ A/A + 40nA 45 μ A/A + 0.7 μ A 45 μ A/A + 0.7 μ A + 200 \times I ² μ A/A 80 μ A/A + 12 μ A 80 μ A/A + 12 μ A + 10 \times I ² μ A/A 360 μ A/A + 480 μ A 360 μ A/A + 580 μ A	Fluke 5720A
DC Current Meter Fixed value	0 A 100 μ A -100 μ A 1 mA -1 mA 10 mA -10 mA 100 mA -100 mA 1 A -1 A	22 pA 2.3 nA 2.3 nA 19 nA 19 nA 0.19 μ A 0.19 μ A 2.5 μ A 2.5 μ A 51 μ A 51 μ A	3458A and DCV Source

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CALIBRATION: ELECTRICAL – DC & LOW FREQUENCY

SITE: CATEGORY I

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
DC Voltage Sources	(0 to 100) mV (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1000) V	6.5 μ V/V + 0.42 μ V 6 μ V/V + 0.42 μ V 5.4 μ V/V + 0.93 μ V 7.6 μ V/V + 42 μ V 7.6 μ V/V + 150 μ V	DMM 3458A
DC Current Sources	(0 to 100) μ A (0.1 to 1.0) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	24 μ A/A + 0.0011 μ A 24 μ A/A + 0.0075 μ A 24 μ A/A + 0.075 μ A 41 μ A/A + 0.75 μ A 120 μ A/A + 14 μ A	3458A and DC current Source
	(1 to 15) A (15 to 100) A (100 to 200) A (200 to 220) A	78 μ A/A + 0.52 μ A 78 μ A/A + 4.2 μ A 150 μ A/A + 570 μ A 21 μ A/A + 64 μ A	Current shunt 9230
Time Interval Sources Interval Range	0.8 ns to 20 ns 20 ns to 10 μ s 10 μ s to 1 ms 1 ms to 1 s 1 s to 10 s	1 ms/s + 9.0 ps 30 ps/s + 1 ns 20 ps/s + 1 ns 10 ps/s + 1 ns 5 ps/s + 1 ns	Measure using scope 86100C and counter 53132A
DC Resistance Meter Fixed value	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	3.6 μ Ω 13 μ Ω / Ω 95 μ Ω / Ω 10 μ Ω / Ω 23 μ Ω / Ω 8.7 μ Ω / Ω 10 μ Ω / Ω 7.7 μ Ω / Ω 8.5 μ Ω / Ω 2.6 μ Ω / Ω 8.5 μ Ω / Ω 7.7 μ Ω / Ω 11 μ Ω / Ω 8.3 μ Ω / Ω 21 μ Ω / Ω 19 μ Ω / Ω 50 μ Ω / Ω 100 μ Ω / Ω	Golden DMM 3458A and Fluke 5720A
DC Resistance Standard	(0 to 10) Ω (10 to 100) Ω (0.1 to 1) k Ω (1 to 10) k Ω (10 to 100) k Ω (0.1 to 1) M Ω (1 to 10) M Ω (10 to 100) M Ω (0.1 to 1) G Ω	21 μ Ω / Ω + 0.8 μ Ω 15 μ Ω / Ω + 0.08 μ Ω 13 μ Ω / Ω + 0.79 m Ω 13 μ Ω / Ω + 7.9 m Ω 13 μ Ω / Ω + 79 m Ω 18 μ Ω / Ω + 2.6 Ω 62 μ Ω / Ω + 0.12 k Ω 580 μ Ω / Ω + 3.7 k Ω 5.80 m Ω / Ω + 0.26 M Ω	Golden DMM 3458A

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CALIBRATION: ELECTRICAL – DC & LOW FREQUENCY

SITE: CATEGORY I

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
AC Voltage Meters	10 Hz to 1 MHz (See Matrix I)	(See Matrix I)	Fluke 5720A
AC Voltage Meters Fixed value	10 Hz to 1 MHz (See Matrix J)	(See Matrix J)	Fluke 5720A and Golden DMM 3458A
AC Current Meters	10 Hz to 10 kHz (See Matrix K)	(See Matrix K)	Fluke 5720A and 5725A
AC Current Meters Fixed Value	10 μ Arms 1 kHz 100 μ Arms 1 kHz 1.0 mArms 1 kHz 10 mArms 1 kHz 100 mArms 1 kHz 1 Arms 1 kHz	8.1 nArms 20 nArms 0.12 μ Arms 1.6 μ Arms 15 μ Arms 0.21 mArms	Golden DMM 3458A and DCV Source
AC Voltage Sources	10 Hz to 1 MHz (See Matrix L)	(See Matrix L)	3548A
AC Current Sources	10 Hz to 5 kHz (See Matrix M)	(See Matrix M)	Golden DMM 3458A and Fluke 5720A

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Matrix I
AC Voltage Meters

Range	(0.22 to 22) mV rms	(22 to 220) mV rms	(0.22 to 2.2) V rms	(2.2 to 22) V rms	(22 to 120) V rms	(120 to 220) V rms	(220 to 250) V rms	(220 to 700) V rms	(700 to 750) V rms
(10 to 20) Hz	240 μ V/V + 4 μ V	240 μ V/V + 12 μ V	240 μ V/V + 40 μ V	240 μ V/V + 400 μ V	240 μ V/V + 4 mV	240 μ V/V + 4 mV	NA	NA	NA
(15 to 50) Hz	NA	NA	NA	NA	NA	NA	300 μ V/V + 16 mV	NA	NA
(20 to 40) Hz	90 μ V/V + 4 μ V	90 μ V/V + 7 μ V	90 μ V/V + 15 μ V	90 μ V/V + 150 μ V	90 μ V/V + 1.5 mV	90 μ V/V + 1.5 mV	NA	NA	NA
(40 to 50) Hz	NA	NA	NA	NA	NA	NA	NA	90 μ V/V + 4 mV	NA
40 Hz to 20 kHz	80 μ V/V + 4 μ V	80 μ V/V + 7 μ V	45 μ V/V + 8 μ V	45 μ V/V + 50 μ V	52 μ V/V + 0.6 mV	52 μ V/V + 0.6 mV	NA	NA	NA
50 Hz to 1 kHz	NA	NA	NA	NA	NA	NA	NA	70 μ V/V + 3.5 mV	1.2 V
(1 to 20) kHz	NA	NA	NA	NA	NA	NA	NA	165 μ V/V + 6.0 mV	NA
(20 to 50) kHz	200 μ V/V + 4 μ V	200 μ V/V + 7 μ V	75 μ V/V + 10 μ V	75 μ V/V + 100 μ V	80 μ V/V + 1.0 mV	80 μ V/V + 1.0 mV	NA	0.6 mV/V + 11 mV	NA
(50 to 100) kHz	0.5 mV/V + 5 μ V	460 μ V/V + 17 μ V	110 μ V/V + 30 μ V	100 μ V/V + 200 μ V	150 μ V/V + 2.5 mV	150 μ V/V + 2.5 mV	NA	2.3 mV/V + 45 mV	NA
(100 to 300) kHz	1.1 mV/V + 10 μ V	0.9 mV/V + 20 μ V	0.42 mV/V + 80 μ V	0.28 mV/V + 0.6 mV	0.9 mV/V + 16 mV	NA	NA	NA	NA
(300 to 500) kHz	1.4 mV/V + 20 μ V	1.4 mV/V + 25 μ V	1.0 mV/V + 0.2 mV	1.0 mV/V + 2.0 mV	4.4 mV/V + 40 mV	NA	NA	NA	NA
500 kHz to 1.0 MHz	2.7 mV/V + 20 μ V	2.7 mV/V + 45 μ V	1.7 mV/V + 0.3 mV	1.5 mV/V + 3.2 mV	8.0 mV/V + 80 mV	NA	NA	NA	NA

Matrix J
AC Voltage Meters - Fixed value

Fixed Value	0.01 mV rms	0.1 mV rms	1.0 V rms	3.0 V rms	10.0 V rms	100.0 V rms	700.0 V rms
10 Hz	NA	NA	NA	NA	1.7 mV	NA	NA
20 Hz	NA	NA	NA	NA	1.0 mV	NA	NA
40 Hz	NA	NA	NA	NA	0.50 mV	NA	NA
1 kHz	3.4 μ V	6.4 μ V	52 μ V	NA	0.50 mV	5.8 mV	53.0 mV
20 kHz	3.5 μ V	8.3 μ V	53 μ V	NA	0.50 mV	5.8 mV	NA
50 kHz	NA	NA	85 μ V	NA	0.85 mV	9.0 mV	NA
100 kHz	9.4 μ V	37 μ V	0.14 mV	0.5 mV	1.2 mV	18.0 mV	NA
300 kHz	21 μ V	69 μ V	0.50 mV	NA	3.4 mV	NA	NA
500 kHz	NA	NA	1.2 mV	NA	12.0 mV	NA	NA
1 MHz	44 μ V	0.18 mV	1.7 mV	NA	18.0 mV	NA	NA
2 MHz	NA	NA	NA	22.0 mV	NA	NA	NA
4 MHz	0.14 mV	0.71 mV	7.1 mV	22.0 mV	NA	NA	NA
8 MHz	NA	0.76 mV	7.6 mV	30.0 mV	NA	NA	NA
10 MHz	NA	2.3 mV	25 mV	76.0 mV	NA	NA	NA

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 Matrix K
AC Current Meters

Range	(9 to 220) $\mu\text{A rms}$	(0.22 to 2.2) mA rms	(2.2 to 22) mA rms	(22 to 220) mA rms	(0.22 to 2.2) A rms	(2.2 to 5) A rms	(5 to 10) A rms
(10 to 20) Hz	250 $\mu\text{A/A}$ + 16 nA	250 $\mu\text{A/A}$ + 40 nA	250 $\mu\text{A/A}$ + 400 nA	250 $\mu\text{A/A}$ + 4.0 μA	NA	NA	NA
(20 to 40) Hz	160 $\mu\text{A/A}$ + 10 nA	160 $\mu\text{A/A}$ + 35 nA	160 $\mu\text{A/A}$ + 350 nA	160 $\mu\text{A/A}$ + 3.5 μA	260 $\mu\text{A/A}$ + 35 μA	NA	NA
40 Hz to 1.0 kHz	120 $\mu\text{A/A}$ + 8 nA	120 $\mu\text{A/A}$ + 35 nA	120 $\mu\text{A/A}$ + 350 nA	120 $\mu\text{A/A}$ + 2.5 μA	260 $\mu\text{A/A}$ + 35 μA	460 $\mu\text{A/A}$ + 170 μA	460 $\mu\text{A/A}$ + 260 μA
(1 to 5) kHz	280 $\mu\text{A/A}$ + 12 nA	200 $\mu\text{A/A}$ + 110 nA	200 $\mu\text{A/A}$ + 550 nA	200 $\mu\text{A/A}$ + 3.5 μA	450 $\mu\text{A/A}$ + 80 μA	950 $\mu\text{A/A}$ + 380 μA	950 $\mu\text{A/A}$ + 420 μA
(5 to 10) kHz	1.1 mA/A + 65 nA	1.1 mA/A + 0.65 μA	1.1 mA/A + 5 μA	1.1 mA/A + 10 μA	0.7 mA/A + 160 μA	3.6 mA/A + 750 μA	3.6 mA/A + 750 μA

 Matrix L
AC Voltage Sources

Range	(1 to 10) mV rms	(10 to 100) mV rms	(0.1 to 1) V rms	(1 to 10) V rms	(10 to 100) V rms	(100 to 700) V rms
10 Hz to 40 Hz	350 $\mu\text{V/V}$ + 3.5 μV	84 $\mu\text{V/V}$ + 4.7 μV	84 $\mu\text{V/V}$ + 46 μV	84 $\mu\text{V/V}$ + 460 μV	240 $\mu\text{V/V}$ + 4.6 mV	NA
40 Hz to 1 kHz	230 $\mu\text{V/V}$ + 1.3 μV	84 $\mu\text{V/V}$ + 2.3 μV	84 $\mu\text{V/V}$ + 23 μV	84 $\mu\text{V/V}$ + 230 μV	240 $\mu\text{V/V}$ + 2.3 mV	0.47 mV/V + 16.1 mV
1 kHz to 20 kHz	350 $\mu\text{V/V}$ + 1.3 μV	170 $\mu\text{V/V}$ + 2.3 μV	170 $\mu\text{V/V}$ + 23 μV	170 $\mu\text{V/V}$ + 230 μV	240 $\mu\text{V/V}$ + 2.3 mV	NA
20 kHz to 50 kHz	1.2 mV/V + 1.3 μV	350 $\mu\text{V/V}$ + 2.3 μV	350 $\mu\text{V/V}$ + 23 μV	350 $\mu\text{V/V}$ + 230 μV	410 $\mu\text{V/V}$ + 2.3 mV	NA
50 kHz to 100 kHz	5.8 mV/V + 1.3 μV	930 $\mu\text{V/V}$ + 2.3 μV	930 $\mu\text{V/V}$ + 23 μV	930 $\mu\text{V/V}$ + 230 μV	1.4 mV/V + 2.3 mV	NA
100 kHz to 200 kHz	46 mV/V + 2.3 μV	3.5 mV/V + 12.0 μV	3.5 mV/V + 120 μV	3.5 mV/V + 1.2 mV	4.6 mV/V + 12.0 mV	NA
200 kHz to 300 kHz	46 mV/V + 2.3 μV	3.5 mV/V + 12.0 μV	3.5 mV/V + 120 μV	3.5 mV/V + 1.2 mV	NA	NA
300 kHz to 1 MHz	NA	12 mV/V + 12 μV	12 mV/V + 120 μV	12 mV/V + 1.2 mV	NA	NA

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 Matrix M
AC Current Sources

Range	(10 to 100) $\mu\text{A rms}$	(0.1 to 100) mA rms	(0.1 to 1) A rms
10 Hz to 20 Hz	4.7 mA/A + 0.035 μA	4.7 mA/A + 23 μA	4.7 mA/A + 230 μA
20 Hz to 45 Hz	1.8 mA/A + 0.035 μA	1.8 mA/A + 23 μA	1.9 mA/A + 230 μA
45 Hz to 100 Hz	0.7 mA/A + 0.035 μA	0.7 mA/A + 23 μA	0.93 mA/A + 230 μA
100 Hz to 3 kHz	0.7 mA/A + 0.035 μA	0.36 $\mu\text{A/A}$ + 23 μA	1.2 mA/A + 230 μA
3 kHz to 5 kHz	NA	0.36 $\mu\text{A/A}$ + 23 μA	1.2 mA/A + 230 μA

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CALIBRATION: ELECTRICAL – RF/MICROWAVE (50 Ω SYSTEM)

SITE: CATEGORY I

Refer Matrix A, B, C, D, E, and script ^[1], ^[4], ^[5] from permanent Lab matrixes

Instrument calibrated/ Measurement parameter	Range	Calibration and Measurement Capability expressed as an uncertainty (±)*	Remarks
Power Sensors Calibration Factors 0 % to 100 %	0.1 MHz	1.7 %	Using Standard power Sensor (with option H84); power splitter and power meter.
	0.3 MHz	1.6 %	
	0.5 MHz	1.6 %	
	1.0 MHz	1.6 %	
	3.0 MHz	1.6 %	
	5.0 MHz	1.6 %	
	10.0 MHz	1.5 %	
	30.0 MHz	1.5 %	
	100.0 MHz	1.6 %	
	300.0 MHz	1.6 %	
	500.0 MHz	1.6 %	
	1.00 GHz	1.6 %	
	1.50 GHz	1.6 %	
	2.00 GHz	1.6 %	
	2.60 GHz	1.6 %	
	3.00 GHz	1.6 %	
	4.00 GHz	1.6 %	
	4.20 GHz	1.6 %	
	5.00 GHz	1.7 %	
	6.00 GHz	1.7 %	
	7.00 GHz	1.7 %	
	8.00 GHz	1.7 %	
	9.00 GHz	1.7 %	
	10.00 GHz	1.7 %	
	11.00 GHz	1.7 %	
	12.00 GHz	1.7 %	
	12.40 GHz	1.7 %	
	13.00 GHz	1.7 %	
	14.00 GHz	1.7 %	
	15.00 GHz	1.8 %	
	16.00 GHz	1.8 %	
	17.00 GHz	1.9 %	
	18.00 GHz	2.3 %	
18.50 GHz	2.3 %		
19.00 GHz	2.4 %		
19.50 GHz	2.4 %		
20.00 GHz	2.4 %		
20.50 GHz	2.4 %		
21.00 GHz	2.4 %		
21.50 GHz	2.4 %		
22.00 GHz	2.4 %		
22.50 GHz	2.5 %		
23.00 GHz	2.5 %		

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CALIBRATION: ELECTRICAL – RF/MICROWAVE (50 Ω SYSTEM)

SITE : CATEGORY I

Instrument calibrated/ Measurement parameter	Range	Calibration and Measurement Capability expressed as an uncertainty (\pm)*	Remarks
Power Sensors Calibration Factors 0 % to 100 % (continued)	23.50 GHz 24.00 GHz 24.50 GHz 25.00 GHz 25.50 GHz 26.00 GHz 26.50 GHz	2.5 % 2.5 % 2.5 % 2.5 % 2.5 % 2.5 % 2.6 %	
Passive Devices Scattering Parameter: Reflection coefficient (linear)	10 kHz to 300 kHz 0 to 0.1 0.1 to 0.5 0.5 to 1.0	0.0022 0.0028 0.0055	Measure using 8753ES, 85054B ^[1]
	300 kHz to 6 GHz 0 to 0.1 0.1 to 0.5 0.5 to 1.0 45 MHz to 50 GHz (See Matrix A)	0.0018 0.0024 0.0052 (See Matrix A)	Measure using E8364B/C
Passive Devices Scattering Parameter: Transmission coefficient	10 kHz to 30 kHz 0 dB to 10 dB 10 dB to 20 dB 20 dB to 30 dB 30 kHz to 6 GHz 0 dB to 10 dB 10 dB to 20 dB 20 dB to 30 dB 30 dB to 40 dB 40 dB to 50 dB 50 dB to 60 dB 60 dB to 70 dB 70 dB to 80 dB 45 MHz to 50 GHz (See Matrix B)	0.062 dB 0.072 dB 0.13 dB 0.057dB 0.060dB 0.061dB 0.073 dB 0.090 dB 0.098 dB 0.15 dB 0.38 dB (See Matrix B)	Measure using 8753ES, 85054B Measure using E8364B/C

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**CALIBRATION: ELECTRICAL – RF/MICROWAVE (50 Ω SYSTEM) FOR
SIGNAL SOURCES**
SITE: CATEGORY I

Instrument calibrated/ Measurement parameter	Range	Calibration and Measurement Capability expressed as an uncertainty (\pm)*	Remarks
Signal Sources Absolute RF Power in Coaxial	(See Matrix C) Exclude 10 MHz to 67 GHz using N8488A Exclude 50 GHz to 67 GHz using V8486A (See Matrix D)	(See Matrix C) Exclude 10 MHz to 67 GHz using N8488A Exclude 50 GHz to 67 GHz using V8486A (See Matrix D)	Power Sensor Power Meter
Signal Sources – RF Power Flatness in Coaxial Line	Exclude 10 MHz to 67 GHz using N8488A Exclude 50 GHz to 67 GHz using V8486A	Exclude 10 MHz to 67 GHz using N8488A Exclude 50 GHz to 67 GHz using V8486A	Power Sensor Power Meter
Signal Sources Harmonic Content	Fundamental Frequency 1 MHz to 25 GHz 0 to 10 dBm Harmonic Frequency 2 MHz to 50 GHz -110 dBm to 0 dBm	0.51dB	E4448A
Signal Sources - Pulse Time Parameters Rise/Fall Time	0 to 10 dBm 10 MHz to 50 GHz	86 ps	86100C 86117A

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SIGNAL SOURCES**
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Instrument calibrated/ Measurement parameter	Range	Calibration and Measurement Capability expressed as an uncertainty (\pm)*	Remarks
Signal Sources – Modulation			
Frequency Modulation	-18 to 30 dBm		E4448A
Peak Frequency Deviation	f_c : 250 kHz to 10 MHz f_m : 20 Hz to 10 kHz Δf : 200 Hz to 40 kHz $\beta > 0.2$	0.015 Hz/Hz	f_c = Carrier Frequency f_m = Modulation Rate Δf = Peak Deviation $\beta = \Delta f / f_m$
	f_c : 250 kHz to 10 MHz f_m : 20 Hz to 10 kHz Δf : 200 Hz to 40 kHz $\beta > 1.2$	0.010 Hz/Hz	
	f_c : 10 MHz to 6.6 GHz f_m : 50 Hz to 200 kHz Δf : 250 Hz to 400 kHz $\beta > 0.2$	0.015 Hz/Hz	
	f_c : 10 MHz to 6.6 GHz f_m : 50 Hz to 200 kHz Δf : 250 Hz to 400 kHz $\beta > 0.45$	0.010 Hz/Hz	
	f_c : 6.6 GHz to 13.2 GHz f_m : 50 Hz to 200 kHz Δf : 250 Hz to 400 kHz $\beta > 0.2$	0.025 Hz/Hz	
	f_c : 6.6 GHz to 13.2 GHz f_m : 50 Hz to 200 kHz Δf : 250 Hz to 400 kHz $\beta > 8$	0.010 Hz/Hz	
	f_c : 13.2 GHz to 31.15 GHz f_m : 50 Hz to 200 kHz Δf : 250 Hz to 400 kHz $\beta > 0.2$	0.038 Hz/Hz	

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CALIBRATION: ELECTRICAL – RF/MICROWAVE (50 Ω SYSTEM) FOR SIGNAL SOURCES**SITE: CATEGORY I**

Instrument calibrated/ Measurement parameter	Range	Calibration and Measurement Capability expressed as an uncertainty (\pm)*	Remarks
Signal Sources – Modulation Frequency Modulation Peak Frequency Deviation (continued)	f_c : 13.2 GHz to 31.15 GHz f_m : 50 Hz to 200 kHz Δf : 250 Hz to 400 kHz $\beta > 16$ f_c : 31.15 GHz to 50 GHz f_m : 50 Hz to 200 kHz Δf : 250 Hz to 400 kHz $\beta > 0.2$ f_c : 31.15 GHz to 50 GHz f_m : 50 Hz to 200 kHz Δf : 250 Hz to 400 kHz $\beta > 32$	0.010 Hz/Hz 0.085 Hz/Hz 0.010 Hz/Hz	E4448A f_c = Carrier Frequency f_m = Modulation Rate Δf = Peak Deviation $\beta = \Delta f / f_m$
Amplitude Modulation Depth	-18 to 30 dBm f_m: 50 Hz to 100 kHz f_c : 100 kHz to 10 MHz Depth: 5 % to 99 % f_c : 10 MHz to 3 GHz Depth: 20 % to 99 % f_c : 10 MHz to 3 GHz Depth: 5 % to 20 % f_c : 3 GHz to 26.5 GHz Depth: 20 % to 99 % f_c : 3 GHz to 26.5 GHz Depth: 5 % to 20 % f_c : 26.5 GHz to 31.15 GHz Depth: 20 % to 99 %	 0.0075 %/° ^[4] 0.005 %/° ^[4] 0.025 %/° ^[4] 0.015 %/° ^[4] 0.045 %/° ^[4] 0.019 %/° ^[4]	E4448A f_c = Carrier Frequency f_m = Modulation Rate

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**CALIBRATION: ELECTRICAL – RF/MICROWAVE (50 Ω SYSTEM) FOR
SIGNAL SOURCES**
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Instrument calibrated/ Measurement parameter	Range	Calibration and Measurement Capability expressed as an uncertainty (\pm)*	Remarks
Amplitude Modulation Depth (continue)	f_c : 26.5 GHz to 31.15 GHz Depth: 5 % to 20 % f_c : 31.15 GHz to 50 GHz Depth: 5 % to 20 % f_c : 31.15 GHz to 50 GHz Depth: 5 % to 20 %	 0.068 %/%% ^[4] 0.06 %/%% ^[4] 0.26 %/%% ^[4]	E4448A f_c = Carrier Frequency f_m = Modulation Rate
Phase Modulation Peak phase deviation	-18 to 30 dBm f_c : 100 kHz to 6.6 GHz $\Delta\Phi > 0.7$ rad f_c : 100 kHz to 6.6 GHz $\Delta\Phi > 0.3$ rad f_c : 6.6 GHz to 13.2 GHz $\Delta\Phi > 2.0$ rad f_c : 6.6 GHz to 13.2 GHz $\Delta\Phi > 0.6$ rad f_c : 13.2 GHz to 26.5 GHz $\Delta\Phi > 4.0$ rad f_c : 13.2 GHz to 26.5 GHz $\Delta\Phi > 1.2$ rad f_c : 26.5 GHz to 31.15 GHz $\Delta\Phi > 4.0$ rad f_c : 26.5 GHz to 31.15 GHz $\Delta\Phi > 1.3$ rad f_c : 31.15 GHz to 50 GHz $\Delta\Phi > 8$ rad f_c : 31.15 GHz to 50 GHz $\Delta\Phi > 2.4$ rad	 0.01 rad/rad 0.03 rad/rad 0.01 rad/rad 0.03 rad/rad 0.01 rad/rad 0.03 rad/rad 0.01 rad/rad 0.03 rad/rad 0.01 rad/rad 0.03 rad/rad	E4448A f_c = Carrier Frequency $\Delta\Phi$ = Phase Deviation

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**CALIBRATION: ELECTRICAL – RF/MICROWAVE (50 Ω SYSTEM) FOR
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SITE: CATEGORY I

Instrument calibrated/ Measurement parameter	Range	Calibration and Measurement Capability expressed as an uncertainty (\pm)*	Remarks
Modulation Rate Amplitude Modulation Rate Frequency Modulation Rate Phase Modulation Rate	$100 \text{ kHz} \leq f_c < 50 \text{ GHz}$ Depth $\geq 20\%$ $f_m \leq 100 \text{ kHz}$ $\beta \geq 0.01$ $f_m \leq 200 \text{ kHz}$ $\beta \geq 0.01$ $f_m \leq 20 \text{ kHz}$	 0.062 Hz 0.062 Hz 0.062 Hz	E4448A $\beta = \Delta f / f_m$ $f_m = \text{Modulation Rate}$
Signal Sources Modulation Distortion Amplitude Modulation Distortion	0.01% to 100% f_m : 20 Hz to 1 kHz f_c : 0.1 to 10 MHz Depth: > 1 % Depth: > 3 % f_m : 20 Hz to 1 kHz f_c : 10 MHz to 26.5 GHz Depth: > 1 % Depth: > 3 % f_m : 20 Hz to 1 kHz f_c : 26.5 to 50 GHz Depth: > 1 % Depth: > 3 % Depth: > 5 %	 0.0012 %/ % + 0.8 % ^[5] 0.0012 %/ % + 0.3 % ^[5] 0.0012 %/ % + 1.0 % ^[5] 0.0012 %/ % + 0.4 % ^[5] 0.0012 %/ % + 6.2 % ^[5] 0.0012 %/ % + 2.0 % ^[5] 0.0012 %/ % + 1.5 % ^[5]	E4448A $f_c = \text{Carrier Frequency}$ $f_m = \text{Modulation Rate}$

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CALIBRATION: ELECTRICAL – RF/MICROWAVE (50 Ω SYSTEM) FOR SIGNAL SOURCES**SITE: CATEGORY I**

Instrument calibrated/ Measurement parameter	Range	Calibration and Measurement Capability expressed as an uncertainty (\pm)*	Remarks
Signal Sources Modulation Distortion	f_c : 1 MHz to 6.6 GHz f_m : 20 Hz to 500 Hz $\Delta\Phi > 0.8$ rad $\Delta\Phi \geq 2.5$ rad	0.0012 %/% + 0.3 % ^[5] 0.0012 %/% + 0.1 % ^[5]	E4448A f_c =Carrier Frequency f_m = Modulation Rate
Phase Modulation Distortion	f_c : 1 MHz to 6.6 GHz f_m : 500 Hz to 1 kHz $\Delta\Phi > 0.4$ rad $\Delta\Phi \geq 1.0$ rad	0.0012 %/% + 0.3 % ^[5] 0.0012 %/% + 0.1 % ^[5]	
	f_c : 6.6 GHz to 13.2 GHz f_m : 20 Hz to 500 Hz $\Delta\Phi > 1.8$ rad $\Delta\Phi \geq 5.5$ rad	0.0012 %/% + 0.3 % ^[5] 0.0012 %/% + 0.1 % ^[5]	
	f_c : 6.6 GHz to 13.2 GHz f_m : 500 Hz to 1 kHz $\Delta\Phi > 0.8$ rad $\Delta\Phi \geq 2.5$ rad	0.0012 %/% + 0.3 % ^[5] 0.0012 %/% + 0.1 % ^[5]	
	f_c : 13.2 GHz to 31.15 GHz f_m : 20 Hz to 500 Hz $\Delta\Phi > 3.5$ rad $\Delta\Phi \geq 10.0$ rad	0.0012 %/% + 0.3 % ^[5] 0.0012 %/% + 0.1 % ^[5]	
	f_c : 13.2 GHz to 31.15 GHz f_m : 500 Hz to 1 kHz $\Delta\Phi > 1.2$ rad $\Delta\Phi \geq 4.0$ rad	0.0012 %/% + 0.3 % ^[5] 0.0012 %/% + 0.1 % ^[5]	
	f_c : 31.15 GHz to 50 GHz f_m : 20 Hz to 500 Hz $\Delta\Phi > 7.5$ rad $\Delta\Phi \geq 19.0$ rad	0.0012 %/% + 0.3 % ^[5] 0.0012 %/% + 0.1 % ^[5]	
	f_c : 31.15 GHz to 50 GHz f_m : 500 Hz to 1 kHz $\Delta\Phi > 3.0$ rad $\Delta\Phi \geq 8.0$ rad	0.0012 %/% + 0.3 % ^[5] 0.0012 %/% + 0.1 % ^[5]	

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CALIBRATION: RF/MICROWAVE (50 Ω SYSTEM) FOR SIGNAL ANALYZER

SITE: CATEGORY I

Instrument calibrated/ Measurement parameter	Range	Calibration and Measurement Capability expressed as an uncertainty (±)*	Remarks
Signal Sources - Modulation Distortion Frequency Modulation Distortion	<p>f_c: 1 MHz to 6.6 GHz f_m: 20 Hz to 1 kHz Δf: 500 Hz to 2 kHz $\Delta f \geq 2.0$ kHz</p> <p>f_c: 6.6 GHz to 13.2 GHz f_m: 20 Hz to 1 kHz $\Delta f > 2.3$ kHz $\Delta f \geq 4.5$ kHz</p> <p>f_c: 13.2 GHz to 31.15 GHz f_m: 20 Hz to 1 kHz $\Delta f > 2.7$ kHz $\Delta f \geq 6.0$ kHz</p> <p>f_c: 31.15 GHz to 50 GHz f_m: 20 Hz to 1 kHz $\Delta f > 4.0$ kHz $\Delta f \geq 12.0$ kHz</p>	<p>0.0012 %/% + 0.3 %^[5] 0.0012 %/% + 0.1 %^[5]</p> <p>0.0012 %/% + 0.3 %^[5] 0.0012 %/% + 0.1 %^[5]</p> <p>0.0012 %/% + 0.3 %^[5] 0.0012 %/% + 0.1 %^[5]</p> <p>0.0012 %/% + 0.3 %^[5] 0.0012 %/% + 0.1 %^[5]</p>	E4448A f_c =Carrier Frequency f_m = Modulation Rate
Signal Sources -Digital Modulation Carrier: 2 MHz to 2.65 GHz Error Vector Magnitude for Modulation Types: MSK, GMSK, BPSK, DQPSK, $\pi/4$ DQPSK, 8PSK, 16QAM and 32QAM, QPSK Phase Error for Modulation Types: MSK, GMSK, BPSK, DQPSK, $n/4$ DQPSK, 8PSK, 16QAM and 32QAM, QPSK Error Vector Magnitude for FSK Modulation	<p>Mod Frequency Span:</p> <p>(1 to 100) kHz (0.1 to 1) MHz 1 MHz to 2.65 GHz</p> <p>Mod Frequency: 3.2 kHz 1.152 kHz</p>	<p>0.31 % rms 0.51 % rms 1.1 % rms</p> <p>0.18 ° rms 0.35 ° rms 0.58 ° rms</p> <p>0.51 % rms 1.60 % rms</p>	89441A
Signal Source - Flatness 0 – 23.90 dBm	100 kHz-80 MHz.	0.0028 dB to 0.10 dB	Measure using Thermal Converter+3458A

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CALIBRATION: RF/MICROWAVE (50 Ω SYSTEM) FOR SIGNAL ANALYZER**SITE: CATEGORY I**

Instrument calibrated/ Measurement parameter	Range	Calibration and Measurement Capability expressed as an uncertainty (±)*	Remarks
Signal Source - Frequency	0.1 Hz to 1 Hz 1 Hz to 10 Hz 10 Hz to 100 Hz 100 Hz to 12.4 GHz 12.4 GHz to 40 GHz	67 pHz 0.88 nHz 4.7 nHz 2.4E-11× Freq (Hz) 2.3E-11× Freq (Hz) + 1.2 Hz	Measure using 5313X, 5315X, 5318X, 5361B.
Signal Analyzers – Absolute RF Power in Coaxial Line	(See Matrix E) Exclude 10 MHz to 67 GHz using N8488A	(See Matrix E) Exclude 10 MHz to 67 GHz using N8488A	Signal Sources, Power Splitters, Power Meters, Power Sensors
Signal Analyzers – Relative RF Power in Coaxial Line	0 dB to 70 dB 70 dB to 110 dB Max power level: 10 dBm 50 MHz to 2 GHz	0.013 dB 0.040 dB	E8257D, Step Attenuators
Signal Analyzers, Frequency Counters - Frequency	0.1 Hz to 1 Hz 1 Hz to 250 kHz 250 kHz to 1 MHz 1 MHz to 40 GHz	2.0E-6 × Freq (Hz) + 0.43 μHz 2.4E-6 × Freq (Hz) 5.2E-9 × Freq (Hz) + 0.14 mHz 5.3E-9 × Freq (Hz)	Measure using 33250A, E8257D.

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CALIBRATION: ELECTRICAL – CAPACITANCE METER

SITE: CATEGORY I

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
4T Capacitance meter	1 pF		Measure using 16380A /16380C
	(20 to 100) Hz	15 fF	
	100 Hz to 1 kHz	0.84 fF	
	1 kHz	0.12 fF	
	1 kHz to 1 MHz	0.56 fF	
	1 MHz	0.14 fF	
	(1 to 2) MHz	0.58 fF	
	2 MHz	0.25 fF	
	10 pF		
	(20 to 100) Hz	19 fF	
	100 Hz to 1 kHz	1.1 fF	
	1 kHz	0.91 fF	
	1 kHz to 1 MHz	0.91 fF	
	1 MHz	0.91 fF	
	(1 to 2) MHz	0.93 fF	
	2 MHz	0.93 fF	
	100 pF		
	(20 to 100) Hz	19 fF	
	100 Hz to 1 kHz	10 fF	
	1 kHz	10 fF	
	1 kHz to 1 MHz	12 fF	
	1 MHz	12 fF	
	(1 to 2) MHz	12 fF	
	2 MHz	12 fF	
1000 pF			
(20 to 100) Hz	0.64 pF		
100 Hz to 1 kHz	0.64 pF		
1 kHz	0.11 pF		
1 kHz to 1 MHz	0.64 pF		
1 MHz	0.12 pF		
(1 to 2) MHz	0.65 pF		
2 MHz	0.18 pF		

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CALIBRATION: ELECTRICAL – CAPACITANCE METER

SITE: CATEGORY I

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
4T Capacitance meter	10 nF		Measure using 16380A /16380C
	(20 to 120) Hz	0.63 pF	
	120 Hz	0.63 pF	
	1 kHz	3.20 pF	
	10 kHz	0.53 pF	
	100 kHz	35 pF	
	100 nF		
	(20 to 120) Hz	4.4 pF	
	120 Hz	4.4 pF	
	1 kHz	4.4 pF	
	10 kHz	4.8 pF	
	100 kHz	5.1 pF	
	1 μF		
	(20 to 120) Hz	2.4 nF	
	120 Hz	55 pF	
	1 kHz	47 pF	
	10 kHz	47 pF	
	100 kHz	89 pF	
	10 μF		
	(20 to 120) Hz	4.1 nF	
120 Hz	0.77 nF		
1 kHz	0.78 nF		
10 kHz	1.8 nF		
100 kHz	8.4 nF		

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CALIBRATION: ELECTRICAL – CAPACITANCE METER

SITE: CATEGORY I

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
4T Dissipation meter	1 pF		Measure using 16380A /16380C
	(20 to 100) Hz	9.5E-03	
	100 Hz to 1 kHz	9.2E-04	
	1 kHz	2.1E-05	
	1 kHz to 1 MHz	3.1E-05	
	1 MHz	3.1E-05	
	(1 to 2) MHz	6.1E-05	
	2 MHz	6.1E-05	
	10 pF		
	(20 to 100) Hz	1.3E-03	
	100 Hz to 1 kHz	8.7E-05	
	1 kHz	2.1E-05	
	1 kHz to 1 MHz	2.1E-05	
	1 MHz	2.1E-05	
	(1 to 2) MHz	2.1E-05	
	2 MHz	2.1E-05	
	100 pF		
	(20 to 100) Hz	1.6E-04	
	100 Hz to 1 kHz	2.1E-05	
	1 kHz	2.1E-05	
	1 kHz to 1 MHz	2.1E-05	
	1 MHz	2.1E-05	
	(1 to 2) MHz	2.1E-05	
	2 MHz	2.1E-05	
	1000 pF		
	(20 to 100) Hz	1.9E-04	
	100 Hz to 1 kHz	2.1E-05	
	1 kHz	2.1E-05	
1 kHz to 1 MHz	3.1E-05		
1 MHz	3.1E-05		
(1 to 2) MHz	6.1E-05		
2 MHz	6.1E-05		

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CALIBRATION: ELECTRICAL – CAPACITANCE METER

SITE: CATEGORY I

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
4T Dissipation meter	10 nF		Measure using 16380A /16380C
	(20 to 120) Hz	2.1E-05	
	120 Hz	2.1E-05	
	1 kHz	2.6E-05	
	10 kHz	2.1E-05	
	100 kHz	2.2E-05	
	100 nF		
	(20 to 120) Hz	3.4E-05	
	120 Hz	3.4E-05	
	1 kHz	2.1E-05	
	10 kHz	4.8E-05	
	100 kHz	4.6E-05	
	1 μF		
	(20 to 120) Hz	4.3E-05	
	120 Hz	4.3E-05	
	1 kHz	2.1E-05	
	10 kHz	3.1E-05	
	100 kHz	3.7E-04	
	10 μF		
	(20 to 120) Hz	4.6E-05	
120 Hz	4.6E-05		
1 kHz	3.1E-05		
10 kHz	2.9E-04		
100 kHz	7.4E-04		

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CALIBRATION: ELECTRICAL – CAPACITANCE METER

SITE: CATEGORY I

Instrument Calibrated/ Measurement Parameter	Range	Calibration and Measurement Capability Expressed as an Uncertainty(\pm)*	Remarks
4T AC Resistance meter	10 Ω		Measure using 42030A
	(20 to 100) Hz	4.3 m Ω	
	100 Hz to 1 MHz	4.5 m Ω	
	1 MHz	3.3 m Ω	
	(1 to 2) MHz	6.0 m Ω	
	2 MHz	5.2 m Ω	
	100 Ω		
	(20 to 100) Hz	51 m Ω	
	100 Hz to 1 MHz	51 m Ω	
	1 MHz	31 m Ω	
	(1 to 2) MHz	57 m Ω	
	2 MHz	41 m Ω	
	1 kΩ		
	(20 to 100) Hz	0.39 Ω	
	100 Hz to 1 MHz	0.39 Ω	
	100 kHz	0.31 Ω	
	1 MHz	0.31 Ω	
	(1 to 2) MHz	0.39 Ω	
	2 MHz	0.31 Ω	
	10 kΩ		
	(20 to 100) Hz	2.3 Ω	
	100 kHz to 1 MHz	3.2 Ω	
	100 kHz	2.1 Ω	
	1 MHz	3.1 Ω	
100 kΩ			
(20 to 100) Hz	26 Ω		
100 kHz to 1 MHz	25 Ω		
100 kHz	28 Ω		
1 MHz	6.6 Ω		

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2. Tan Phaik Geok
3. Tang Suet Wei