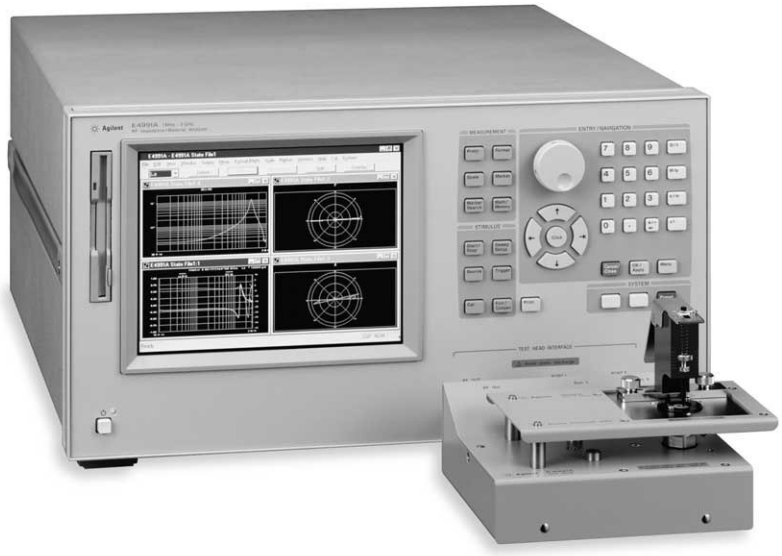
Agilent
E4991A RF Impedance/Material Analyzer

Data Sheet



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Definitions

All specifications apply over a 5 °C to 40 °C range (unless otherwise stated) and 30 minutes after the instrument has been turned on.

Specification (spec.)
Warranted performance. Specifications include guardbands to account for the expected statistical performance distribution, measurement uncertainties, and changes in performance due to environmental conditions.

Supplemental information is intended to provide information useful in applying the instrument, but that is not covered by the product warranty. The information is denoted as typical, or nominal.

Typical (typ.)
Expected performance of an average unit which does not include guardbands. It is not covered by the product warranty.

Nominal (nom.)
A general, descriptive term that does not imply a level of performance. It is not covered by the product warranty.

Measurement Parameters and Range

Measurement parameters

Impedance parameters:
$|Z|$, $|Y|$, L_s, L_p, C_s, C_p, $R_s(R)$, R_p, X, G, B, D, Q, θ_z, θ_y, $|\Gamma|$, Γ_x, Γ_y, θ_γ

Material parameters (option E4991A-002):
(see *"Option E4991A-002 material measurement (typical)"* on page 17)
Permittivity parameters: $|\varepsilon_r|$, ε_r', ε_r'', tanδ
Permeability parameters: $|\mu_r|$, μ_r', μ_r'', tanδ

Measurement range

Measurement range (|Z|):
130 mΩ to 20 kΩ.
(Frequency= 1 MHz,
Point averaging factor ≥ 8,
Oscillator level= –3 dBm; = –13 dBm; or = –23 dBm,
Measurement accuracy ≤ ±10%,
Calibration is performed within 23 °C ±5 °C,
Measurement is performed within ±5 °C of calibration temperature)

Source Characteristics

Frequency

Range:
1 MHz to 3 GHz

Resolution:
1 mHz

Accuracy:
without Option E4991A-1D5:
±10 ppm (23 °C ±5 °C)
±20 ppm (5 °C to 40 °C)
with Option E4991A-1D5:
±1 ppm (5 °C to 40 °C)

Stability:
with Option E4991A-1D5:
±0.5 ppm/year (5 °C to 40 °C)

Oscillator level

Range:
Power (when 50 Ω load is connected to test port):
–40 dBm to 1 dBm (frequency ≤ 1 GHz)
–40 dBm to 0 dBm (frequency > 1 GHz[1])
Current (when short is connected to test port):
0.0894 mArms to 10 mArms (frequency ≤ 1 GHz)
0.0894 mArms to 8.94 mArms (frequency > 1 GHz[1])
Voltage (when open is connected to test port):
4.47 mVrms to 502 mVrms (frequency ≤ 1 GHz)
4.47 mVrms to 447 mVrms (frequency > 1 GHz[1])

Resolution:
0.1 dB[2]

Accuracy:
(Power, when 50 Ω load is connected to test port)
Frequency ≤ 1 GHz:
±2 dB (23 °C ±5 °C)
±4 dB (5 °C to 40 °C)
Frequency > 1 GHz:
±3 dB (23 °C ±5 °C)
±5 dB (5 °C to 40 °C)
with Option E4991A-010:
Frequency ≤ 1 GHz
±3.5 dB (23 °C ± 5 °C)
±5.5 dB (5 °C to 40 °C)
Frequency > 1 GHz
±5.6 dB (23 °C ± 5 °C)
±7.6 dB (5 °C to 40 °C)

Output impedance

Output impedance:
50 Ω (nominal)

DC Bias (Option E4991A-001)

DC voltage bias

Range:
0 to ±40 V

Resolution:
1 mV

Accuracy:
±{0.1% + 6 mV + (Idc[mA] x 20 Ω)[mV]}
(23 °C ±5 °C)
±{0.2% + 12 mV + (Idc[mA] x 40 Ω)[mV]}
(5 °C to 40 °C)

DC current bias

Range:
100 µA to 50 mA, –100 µA to –50 mA

Resolution:
10 µA

Accuracy:
±{0.2% + 20 µA + (Vdc[V] / 10 kΩ)[mA]}
(23 °C ±5 °C)
±{0.4% + 40 µA + (Vdc[V] / 5 kΩ)[mA]}
(5 °C to 40 °C)

DC bias monitor

Monitor parameters:
Voltage and current

Voltage monitor accuracy:
±{0.5% + 15 mV + (Idc[mA] x 2 Ω)[mV]}
(23 °C ±5 °C, typical)
±{1.0% + 30 mV + (Idc[mA] x 4 Ω)[mV]}
(5 °C to 40 °C, typical)

Current monitor accuracy:
±{0.5% + 30 µA + (Vdc[V] / 40 k Ω)[mA]}
(23 °C ±5 °C, typical)
±{1.0% + 60 µA + (Vdc[V] / 20 k Ω)[mA]}
(5 °C to 40 °C, typical)

1. It is possible to set more than 0 dBm (447 mV, 8.94 mA) oscillator level at frequency > 1 GHz. However, the characteristics at this setting are not guaranteed.
2. When the unit is set at mV or mA, the entered value is rounded to 0.1 dB resolution.

Probe Station Connection Kit (Option E4991A-010)

Oscillator level

Power accuracy:
Frequency ≤ 1 GHz:
±5.5 dB (5 °C to 40 °C)
Frequency > 1 GHz:
±7.6 dB (5 °C to 40 °C)

Sweep Characteristics

Sweep conditions

Sweep parameters:
Frequency, oscillator level (power, voltage, current), DC bias voltage, DC bias current

Sweep range setup:
Start/stop or center/span

Sweep types:
Frequency sweep: linear, log, segment
Other parameters sweep: linear, log

Sweep mode:
Continuous, single

Sweep directions:
Oscillator level, DC bias (voltage and current): up sweep, down sweep
Other parameters sweep: up sweep

Number of measurement points:
2 to 801

Delay time:
Types: point delay, sweep delay, segment delay
Range: 0 to 30 sec
Resolution: 1 msec

Segment sweep

Available setup parameters for each segment:
Sweep frequency range, number of measurement points, point averaging factor, oscillator level (power, voltage, or current), DC bias (voltage or current), DC bias limit (current limit for voltage bias, voltage limit for current bias)

Number of segments:
1 to 16

Sweep span types:
Frequency base or order base

Measurement Accuracy

Conditions for defining accuracy

Temperature:
23 °C ±5 °C

Accuracy-specified plane:
7-mm connector of test head

Accuracy defined measurement points:
Same points at which the calibration is done.

Accuracy when open/short/load calibration is performed

|Z|, |Y|: $\pm(E_a + E_b)$ [%]
(see Figures 1 through 4 for examples of calculated accuracy)

θ: $\pm \dfrac{(E_a + E_b)}{100}$ [rad]

L, C, X, B: $\pm (E_a + E_b) \times \sqrt{(1 + D_x^2)}$ [%]

R, G: $\pm (E_a + E_b) \times \sqrt{(1 + Q_x^2)}$ [%]

D:

at $\left|D_x \tan\left(\dfrac{E_a + E_b}{100}\right)\right| < 1$ $\quad \pm \dfrac{(1 + D_x^2)\tan\left(\dfrac{E_a + E_b}{100}\right)}{1 \mp D_x \tan\left(\dfrac{E_a + E_b}{100}\right)}$

at $D_x \leq 0.1$ $\quad \pm \dfrac{E_a + E_b}{100}$

Q:

at $\left|Q_x \tan\left(\dfrac{E_a + E_b}{100}\right)\right| < 1$ $\quad \pm \dfrac{(1 + Q_x^2)\tan\left(\dfrac{E_a + E_b}{100}\right)}{1 \mp Q_x \tan\left(\dfrac{E_a + E_b}{100}\right)}$

at $\dfrac{10}{E_a + E_b} \geq Q_x \geq 10$ $\quad \pm Q_x^2 \dfrac{E_a + E_b}{100}$

Accuracy when open/short/load/low-loss capacitor calibration is performed

|Z|, |Y|: $\pm(E_a + E_b)$ [%]

θ: $\pm \dfrac{E_c}{100}$ [rad]

L, C, X, B: $\pm \sqrt{(E_a + E_b)^2 + (E_c D_x)^2}$ [%]

R, G: $\pm \sqrt{(E_a + E_b)^2 + (E_c Q_x)^2}$ [%]

D:

at $\left|D_x \tan\left(\dfrac{E_c}{100}\right)\right| < 1 \pm \dfrac{(1 + D_x^2)\tan\left(\dfrac{E_c}{100}\right)}{1 \mp D_x \tan\left(\dfrac{E_c}{100}\right)}$

at $D_x \leq 0.1$ $\pm \dfrac{E_c}{100}$

Q:

at $\left|Q_x \tan\left(\dfrac{E_c}{100}\right)\right| < 1 \pm \dfrac{(1 + Q_x^2)\tan\left(\dfrac{E_c}{100}\right)}{1 \mp Q_x \tan\left(\dfrac{E_c}{100}\right)}$

at $\dfrac{10}{E_c} \geq Q_x \geq 10$ $\pm Q_x^2 \dfrac{E_c}{100}$

(See Figure 5)

Definition of each parameter

Dx = Measurement value of D

Qx = Measurement value of Q

Ea = (Within ±5 °C from the calibration temperature. Measurement accuracy applies when the calibration is performed at 23 °C ±5 °C. When the calibration is performed beyond 23 °C ±5 °C, measurement error doubles.)

at oscillator level ≥ –33 dBm:
- ±0.65 [%] (1 MHz ≤ Frequency ≤ 100 MHz)
- ±0.8 [%] (100 MHz < Frequency ≤ 500 MHz)
- ±1.2 [%] (500 MHz < Frequency ≤ 1 GHz)
- ±2.5 [%] (1 GHz < Frequency ≤ 1.8 GHz)
- ±5 [%] (1.8 GHz < Frequency ≤ 3 GHz)

at Oscillator level < –33 dBm:
- ±1 [%] (1 MHz ≤ Frequency ≤ 100 MHz)
- ±1.2 [%] (100 MHz < Frequency ≤ 500 MHz)
- ±1.2 [%] (500 MHz < Frequency ≤ 1 GHz)
- ±2.5 [%] (1 GHz < Frequency ≤ 1.8 GHz)
- ±5 [%] (1.8 GHz < Frequency ≤ 3 GHz)

Eb = $\pm \left(\dfrac{Z_s}{|Z_x|} + Y_o \bullet |Z_x|\right) \times 100$ [%]

(|Zx|: measurement value of |Z|)

Ec = $\pm \left(0.06 + \dfrac{0.08 \times F}{1000}\right)$ [%]

(F: frequency [MHz], typical)

Zs = (Within ±5 °C from the calibration temperature. Measurement accuracy applies when the calibration is performed at 23 °C ±5 °C. When the calibration is performed beyond 23 °C ±5 °C, the measurement accuracy decreases to half that described.
F: frequency [MHz].)

at oscillator level = –3 dBm, –13 dBm, or –23 dBm:
- $\pm(13 + 0.5 \times F)$ [mΩ] (averaging factor ≥ 8)
- $\pm(25 + 0.5 \times F)$ [mΩ] (averaging factor ≤ 7)

at oscillator level ≥ –33 dBm
- $\pm(25 + 0.5 \times F)$ [mΩ] (averaging factor ≥ 8)
- $\pm(50 + 0.5 \times F)$ [mΩ] (averaging factor ≤ 7)

at oscillator level < –33 dBm
- $\pm(50 + 0.5 \times F)$ [mΩ] (averaging factor ≥ 8)
- $\pm(100 + 0.5 \times F)$ [mΩ] (averaging factor ≤ 7)

Yo = (Within ±5 °C from the calibration temperature. Measurement accuracy applies when the calibration is performed at 23 °C ±5 °C. When the calibration is performed beyond 23 °C ±5 °C, the measurement accuracy decreases to half that described.
F: frequency [MHz].)

at oscillator level = –3 dBm, –13 dBm, –23 dBm:
- $\pm(5 + 0.1 \times F)$ [μ*S*] (averaging factor ≥ 8)
- $\pm(10 + 0.1 \times F)$ [μ*S*] (averaging factor ≤ 7)

at oscillator level ≥ –33 dBm:
- $\pm(10 + 0.1 \times F)$ [μ*S*] (averaging factor ≥ 8)
- $\pm(30 + 0.1 \times F)$ [μ*S*] (averaging factor ≤ 7)

at oscillator level < –33 dBm
- $\pm(20 + 0.1 \times F)$ [μ*S*] (averaging factor ≥ 8)
- $\pm(60 + 0.1 \times F)$ [μ*S*] (averaging factor ≤ 7)

Measurement Accuracy
(continued)

Examples of calculated impedance measurement accuracy

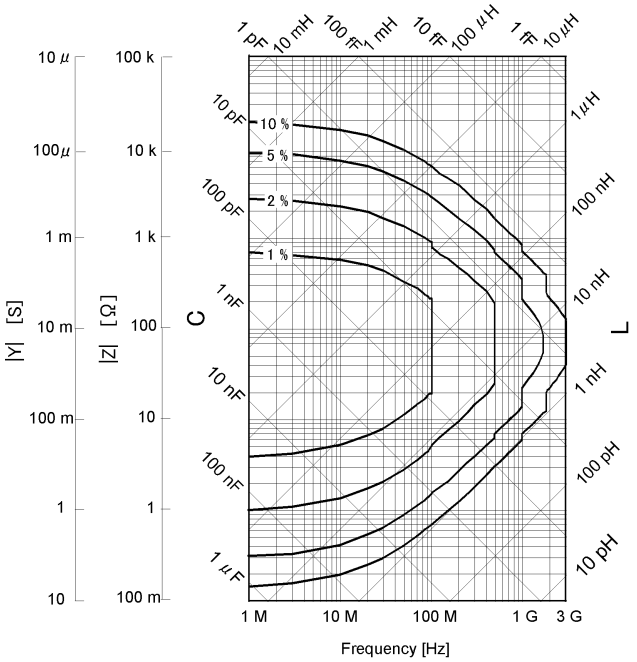

Figure 1. |Z|, |Y| Measurement accuracy when open/short/load calibration is performed. Oscillator level = –23 dBm, –13 dBm, –3 dBm. Point averaging factor ≥ 8 within ±5 °C from the calibration temperature.

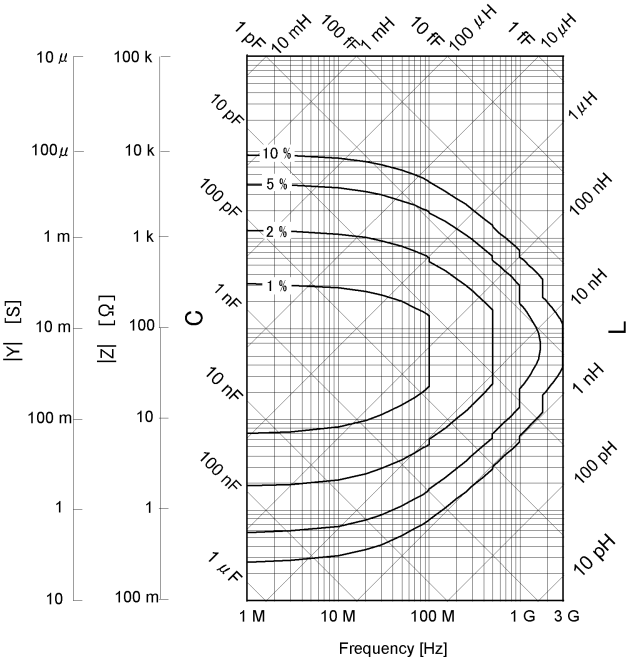

Figure 2. |Z|, |Y| Measurement accuracy when open/short/load calibration is performed. Oscillator level ≥ –33 dBm. Point averaging factor ≥ 8 within ±5 °C from the calibration temperature.

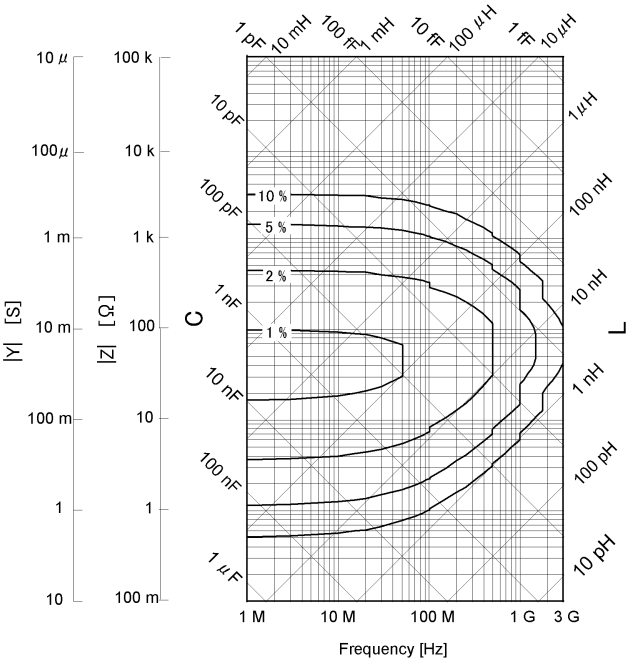

Figure 3. |Z|, |Y| Measurement accuracy when open/short/load calibration is performed. Oscillator level ≥ –33 dBm. Point averaging factor ≤ 7 within ±5 °C from the calibration temperature.