Agilent 4291B

RF Impedance/Material Analyzer

Data Sheet

Overview

Specifications describe the instrument's warranted performance over the temperature range of 0°C to 40°C (except as noted). Supplemental characteristics are intended to provide information that is useful in applying the instrument by giving non-warranted performance parameters. These are denoted as "typical," "nominal," or "approximate." Warm-up time must be greater than or equal to 30 minutes after power on for all specifications. Specifications of the stimulus characteristics and measurement accuracy are defined at the tip of APC-7 connector on the test head connected to the instrument.

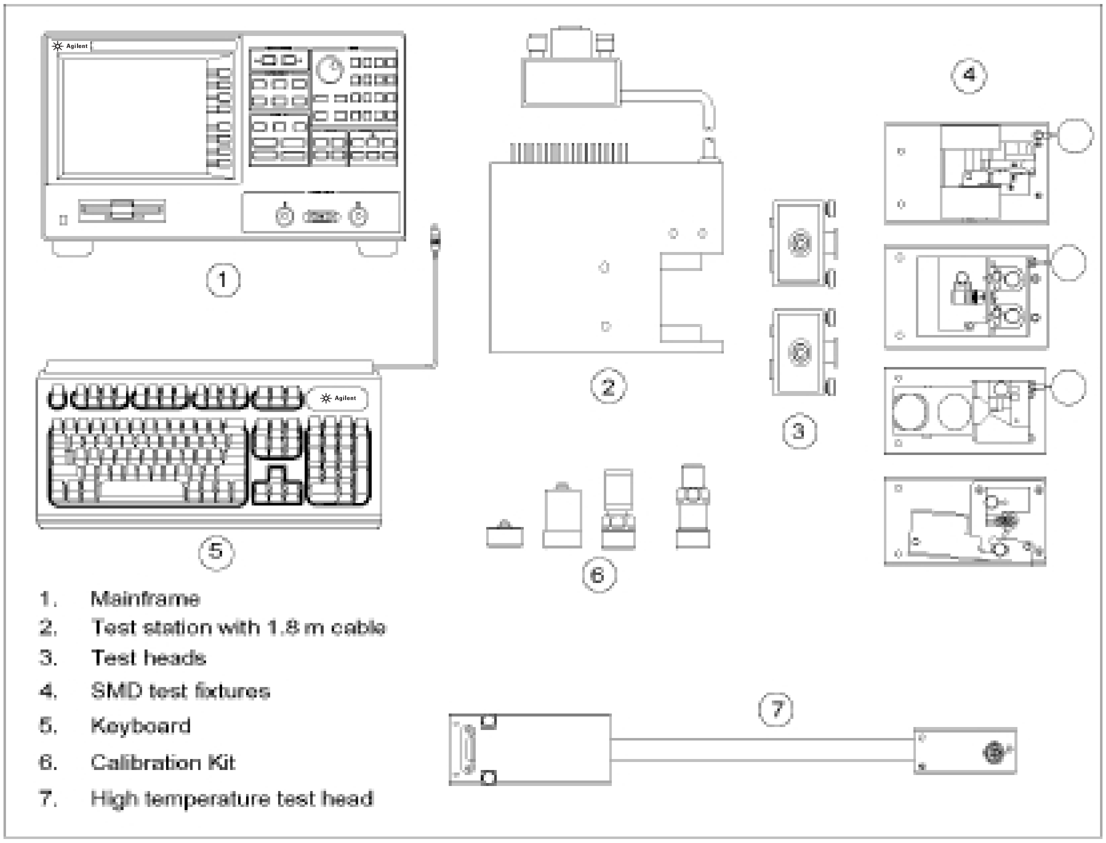

Figure 1-1

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Agilent 4291B RF Impedance/Material Analyzer

Measurement Parameters

Impedance parameters

$|Z|$, θ_z, $|Y|$, θ_y, R, X, G, B, C_p, C_s, L_p, L_s, R_p, R_s, D, Q, $|\Gamma|$, θ_y, Γ_x, Γ_y

Stimulus Characteristics

Frequency Characteristics

Operating frequency	1 MHz to 1.8 GHz
Frequency resolution	1 mHz

Frequency reference

Accuracy

@ 23±5°C	< ±10 ppm

Precision frequency reference (Option 1D5)

Accuracy

@ 0°C to 40°C	< ±1 ppm

Source Characteristics

OSC level

Voltage range

@ 1 MHz ≤ Frequency ≤ 1 GHz (When terminal is open)	0.2 mV_{rms} to 1 V_{rms}
@ 1 GHz < Frequency ≤ 1.8 GHz (When terminal is open)	0.2 mV_{rms} to 0.5 V_{rms}

Current range

@ 1 MHz ≤ Frequency ≤ 1 GHz (When terminal is shorted).	4 μA_{rms} to 20 mA_{rms}
@ 1 GHz < Frequency ≤ 1.8 GHz (When terminal is shorted).	4 μA_{rms} to 10 mA_{rms}

Power range

@ 1 MHz ≤ Frequency ≤ 1 GHz (When terminating with 50 Ω).	–67 dBm to 7 dBm
@ 1 GHz < Frequency ≤ 1.8 GHz (When terminating with 50 Ω)	–67 dBm to 1 dBm

OSC level resolution

AC voltage resolution

$0.22\ V_{rms} < V_{OSC} \le 1\ V_{rms}$	2 mV
$70\ mV_{rms} < V_{OSC} \le 220\ mV_{rms}$	0.5 mV
$22\ mV_{rms} < V_{OSC} \le 70\ mV_{rms}$	0.2 mV
$7\ mV_{rms} < V_{OSC} \le 22\ mV_{rms}$	0.05 mV
$2.2\ mV_{rms} < V_{OSC} \le 7\ mV_{rms}$	0.02 mV
$0.7\ mV_{rms} < V_{OSC} \le 2.2\ mV_{rms}$	0.005 mV
$0.2\ mV_{rms} \le V_{OSC} \le 0.7\ mV_{rms}$	0.002 mV

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AC current resolution	
$4.4\ \mathrm{mA_{rms}} < I_{OSC} \leq 20\ \mathrm{mA_{rms}}$	40 μA
$1.4\ \mathrm{mA_{rms}} < I_{OSC} \leq 4.4\ \mathrm{mA_{rms}}$	10 μA
$0.44\ \mathrm{mA_{rms}} < I_{OSC} \leq 1.4\ \mathrm{mA_{rms}}$	4 μA
$140\ \mu\mathrm{A_{rms}} < I_{OSC} \leq 440\ \mu\mathrm{yA_{rms}}$	1 μA
$44\ \mu\mathrm{A_{rms}} < I_{OSC} \leq 140\ \mu\mathrm{A_{rms}}$	0.4 μA
$14\ \mu\mathrm{A_{rms}} < I_{OSC} \leq 44\ \mu\mathrm{A_{rms}}$	0.1 μA
$4\ \mu\mathrm{A_{rms}} \leq I_{OSC} \leq 14\ \mu\mathrm{A_{rms}}$	0.04 μA
AC power resolution	0.1 dBm

OSC level accuracy . . . . $A + B + \frac{6_{[\mathrm{dB}]} \times f_{[\mathrm{MHz}]}}{1800}$ dB

where,

A depends on temperature conditions as follows:

@ within referenced to 23±5°C	2 dB
@ other environmental temperature conditions.	4 dB

B depends on OSC level as follows:

@ $V_{OSC} \geq 250\ \mathrm{mV_{rms}}$ $(I_{OSC} \geq 5\ \mathrm{mA_{rms}})$ $(P_{OSC} \geq -5\ \mathrm{dBm})$	0 dB
@ $250\ \mathrm{mV_{rms}} > V_{OSC} \geq 2.5\ \mathrm{mV_{rms}}$ $(5\ \mathrm{mA_{rms}} > I_{OSC} \geq 50\ \mu\mathrm{A_{rms}})$ $(-5\ \mathrm{dBm} > P_{OSC} \geq -45\ \mathrm{dBm})$	1 dB
@ other OSC level	2 dB

Definition of OSC level

- Voltage level: 2 × voltage level across the 50 Ω which is connected to the output terminal (This level is approximately equal to the level when a terminal is open.)
- Current level: 2 × current level through the 50 Ω which is connected to the output terminal (This level is approximately equal to the level when a terminal is shorted.)
- Power level: when terminating with 50 Ω

OSC level accuracy	½ of specification value (typical)
Connector	APC-7
Output impedance	50 Ω (Nominal value)
DC bias (Option 001)	
DC voltage level	0 to ±40V
DC current level	20 μA to 100 mA and –20 μA to –100 mA
DC level resolution	1 mV, 20 μA
DC level accuracy	
@ 23±5°C	
Voltage	$0.1\ \% + 4\ \mathrm{mV} + (I_{dc\,[\mathrm{mA}]} \times 5_{\,[\Omega]})\ \mathrm{mV}$
Current.	$0.5\ \% + 30\ \mu\mathrm{A} + (V_{dc\,[\mathrm{V}]} / 10_{\,[\mathrm{k}\Omega]})\ \mathrm{mA}$
@ 8 to 18°C and 28 to 38°C	
Voltage	$0.2\ \% + 8\ \mathrm{mV} + (I_{dc\,[\mathrm{mA}]} \times 10_{\,[\Omega]})\ \mathrm{mV}$
Current	$1\ \% + 60\ \mu\mathrm{A} + (V_{dc\,[\mathrm{v}]} / 5_{\,[\mathrm{k}\Omega]})\ \mathrm{mA}$
@ 0 to 8°0C and 38 to 40°C	
Voltage	$0.3\ \% + 12\ \mathrm{mV} + (I_{dc\,[\mathrm{mA}]} \times 15_{\,[\Omega]})\ \mathrm{mV}$
Current	$1.5\ \% + 90\ \mu\mathrm{A} + (V_{dc\,[\mathrm{V}]} \times 3/10_{\,[\mathrm{k}\Omega]})\ \mathrm{mA}$

Level monitor

Monitor parameters	OSC level (voltage, current), DC bias (voltage, current)
Monitor accuracy	
OSC level	Same as OSC level accuracy (typical)
DC bias	Twice as bad as specifications of dc level accuracy (typical)

Sweep Characteristics

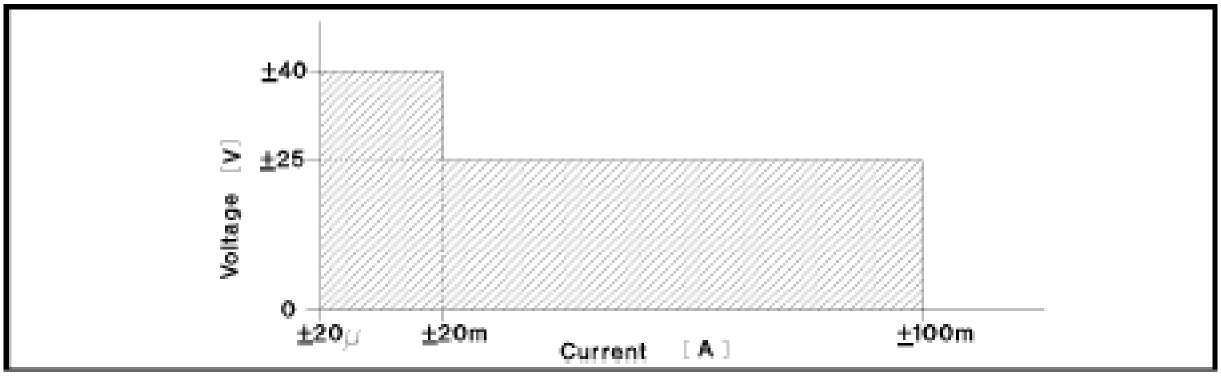

Figure 1-2. DC Voltage and Current Level Range (Typical)

Sweep parameters	Frequency, OSC level (voltage), DC bias voltage/current
Sweep setup	Start Stop, or Center Span
Sweep type	
Frequency sweep	Linear, Log, Zero-span, List
Other sweep parameters	Linear, Log, Zero-span
Sweep mode	Continuous, Single, Manual, Number of groups
Sweep direction	
AC level, DC bias (voltage and current)	Up sweep, Down sweep
Other sweep parameters	Up sweep
Number of measurement points	2 to 801 points
Averaging	Sweep average, Point average
Delay time	Point delay time, Sweep delay time
Measurement circuit mode	Series circuit mode, parallel circuit mode

Calibration/Compensation

Calibration function	Open/Short/50 Ω calibration, Low loss calibration
Compensation function	Open/Short/Load compensation, Port extension, Electric length

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Measurement Accuracy

Conditions of accuracy specifications

- Open/Short/50 Ω calibration must be done. Calibration ON.
- Averaging (on point) factor is larger than 32 at which calibration is done if Cal points is set to USER DEF.
- Measurement points are same as the calibration points.
- Environmental temperature is within ±5°C of temperature at which calibration is done, and within l3°C to 33°C. Beyond this environmental temperature condition, accuracy is twice as bad as specified.

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

The illustrations of |Z| and |Y| accuracy are shown in Figures l-3 to 1-6.

θ Accuracy . . . . $\pm\frac{(E_a + E_b)}{100}$ [rad]

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

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

D Accuracy (ΔD)

@ $|D_x \tan(\frac{E_a + E_b}{100})| < 1$ . . . . $\pm\dfrac{(1 + D_x^2)\tan(\frac{E_a + E_b}{100})}{1 \mp D_x \tan(\frac{E_a + E_b}{100})}$

Especially, @ $D_x \leq 0.1$. . . . . $\pm\frac{(E_a + E_b)}{100}$

Q Accuracy (ΔQ)

@ $|Q_x \tan(\frac{E_a + E_b}{100})| < 1$. . . . . $\pm\dfrac{(1 + Q_x^2)\tan(\frac{E_a + E_b}{100})}{(1 \mp Q_x)\tan(\frac{E_a + E_b}{100})}$

Especially, @ $\frac{10}{(E_a + E_b)} \geq Q_x \geq 10$ . . . . $\pm Q_x^2 \frac{(E_a + E_b)}{100}$

Where,

D_x : Measured vaulue of D

E_a : depends on measurement frequency as follows:

@ 1 MHz ≤ Frequency ≤ 100 MHz	0.6
@ 100 MHz < Frequency ≤ 500 MHz	0.8
@ 500 MHz < Frequency ≤ 1000 MHz	1.2
@ 1000 MHz < Frequency ≤ 1800 MHz	2.0

E_b = $(Z_s/|Z_x| + Y_o|Z_x| \times 100$

Q_x : Measured value of Q

Z_x : impedance measurement value [Ω]

Z_s and **Y_o** depend on number of point averaging (N_{av}), OSC level (V_{OSC}), impedance measurement value (Z_x) and the test head used as follows:

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Table 1-1. Z_s and Y_o When High Impedance Test Head Is Used

	Measurement Conditions			
Number of Point Averaging (N_{av})	OSC Signal Level (V_{osc})	Meas. Impedance (Z_x)	Z_S [Ω]	Y_o [S]
$1 \leq N_{av} \leq 7$	$V_{osc} < 0.02V$	–	$\frac{0.02}{V_{osc}}$ x (0.2 + 0.001 x $f_{[MHz]}$)	$\frac{0.02}{V_{osc}}$ x (5 x 10^{-5} + 2 x 10^{-7} x $f_{[MHz]}$)
	$0.02V \leq V_{osc} < 0.12V$	–	0.2 + 0.001 x $f_{[MHz]}$	5 x 10^{-5} + 2 x 10^{-7} x $f_{[MHz]}$
	$0.12V \leq V_{osc}$	$Z_x \geq 500$ Ω	0.2 + 0.001 x $f_{[MHz]}$	5 x 10^{-6} + 2 x 10^{-7} x $f_{[MHz]}$
		$Z_x < 500$ Ω	0.2 + 0.001 x $f_{[MHz]}$	2 x 10^{-5} + 2 x 10^{-7} x $f_{[MHz]}$
$N_{av} \geq 8$	$V_{osc} < 0.02V$	–	$\frac{0.02}{V_{osc}}$ x (0.1 + 5 x 10^{-4} x $f_{[MHz]}$)	$\frac{0.02}{V_{osc}}$ x (2 x 10^{-5} + 1 x 10^{-7} x $f_{[MHz]}$)
	$0.02V \leq V_{osc} < 0.12V$	–	0.1 + 5 x 10^{-4} x $f_{[MHz]}$	2 x 10^{-5} + 1 x 10^{-7} x $f_{[MHz]}$
	$0.12V \leq V_{osc}$	$Z_x \geq 500$ Ω	0.1 + 5 x 10^{-4} x $f_{[MHz]}$	2 x 10^{-6} + 1 x 10^{-7} x $f_{[MHz]}$
		$Z_x < 500$ Ω	0.1 + 5 x 10^{-4} x $f_{[MHz]}$	7 x 10^{-6} + 1 x 10^{-7} x $f_{[MHz]}$

Table 1-2. Z_s and Y_o When Low Impedance Test Head Is Used

	Measurement Conditions			
Number of Point Averaging (N_{av})	OSC Signal Level (V_{osc})	Meas. Impedance (Z_x)	Z_S [Ω]	Y_o [S]
$1 \leq N_{av} \leq 7$	$V_{osc} < 0.02V$	–	$\frac{0.02}{V_{osc}}$ x (0.1 + 0.001 x $f_{[MHz]}$)	$\frac{0.02}{V_{osc}}$ x (1 x 10^{-4} + 2 x 10^{-7} x $f_{[MHz]}$)
	$0.02V \leq V_{osc} < 0.12V$	–	0.1 + 0.001 x $f_{[MHz]}$	1 x 10^{-4} + 2 x 10^{7} x $f_{[MHz]}$
	$0.12V \leq V_{osc}$	$Z_x \leq 5$ Ω	0.01 + 0.001 x $f_{[MHz]}$	1 x 10^{-4} + 2 x 10^{-7} x $f_{[MHz]}$
		$Z_x > 5$ Ω	0.05 + 0.001 x $f_{[MHz]}$	1 x 10^{-4} + 2 x 10^{-7} x $f_{[MHz]}$
$N_{av} \geq 8$	$V_{osc} < 0.02V$	–	$\frac{0.02}{V_{osc}}$ x (0.05 + 5 x 10^{-4} x $f_{[MHz]}$)	$\frac{0.02}{V_{osc}}$ x (3 x 10^{-5} + 1 x 10^{-7} x $f_{[MHz]}$
	$0.02V \leq V_{osc} < 0.12V$	–	0.05 + 5 x 10^{-4} x $f_{[MHz]}$	3 x 10^{-5} + 1 x 10^{-7} x $f_{[MHz]}$
	$0.12V \leq V_{osc}$	$Z_x \leq 5$ Ω	0.01 + 5 x 10^{-4} x $f_{[MHz]}$	3 x 10^{-5} + 1 x 10^{-7} x $f_{[MHz]}$
		$Z_x > 5$ Ω	0.02 + 5 x 10^{-4} x $f_{[MHz]}$	3 x 10^{-5} + 1 x 10^{-7} x $f_{[MHz]}$

At the following frequency points, instrument spurious characteristics could occasionally cause measurement errors to exceed specified value because of instrument spurious characteristics.

10.71 MHz 17.24 MHz 21.42 MHz 42.84 MHz
514.645 MHz 686.19333 MHz 1029.29 MHz 1327.38666 MHz

See “EMC” under “Others” in “General Characteristics.”

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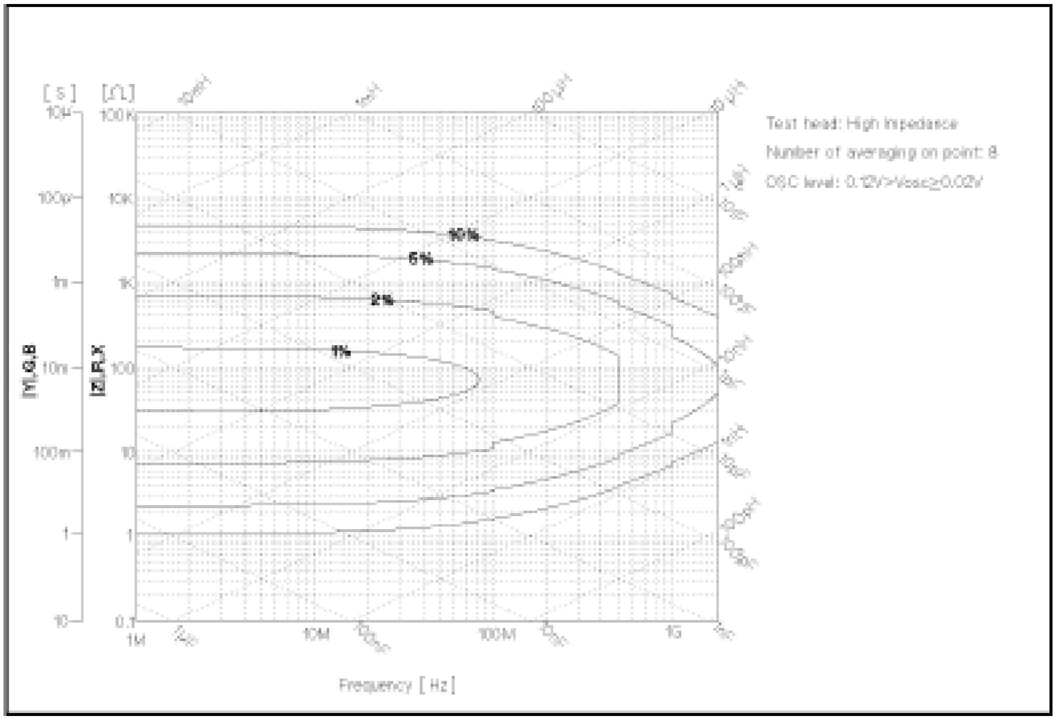

Figure 1-3. Impedance Measurement Accuracy Using High Impedance Test Head (@ Low OSC Level)

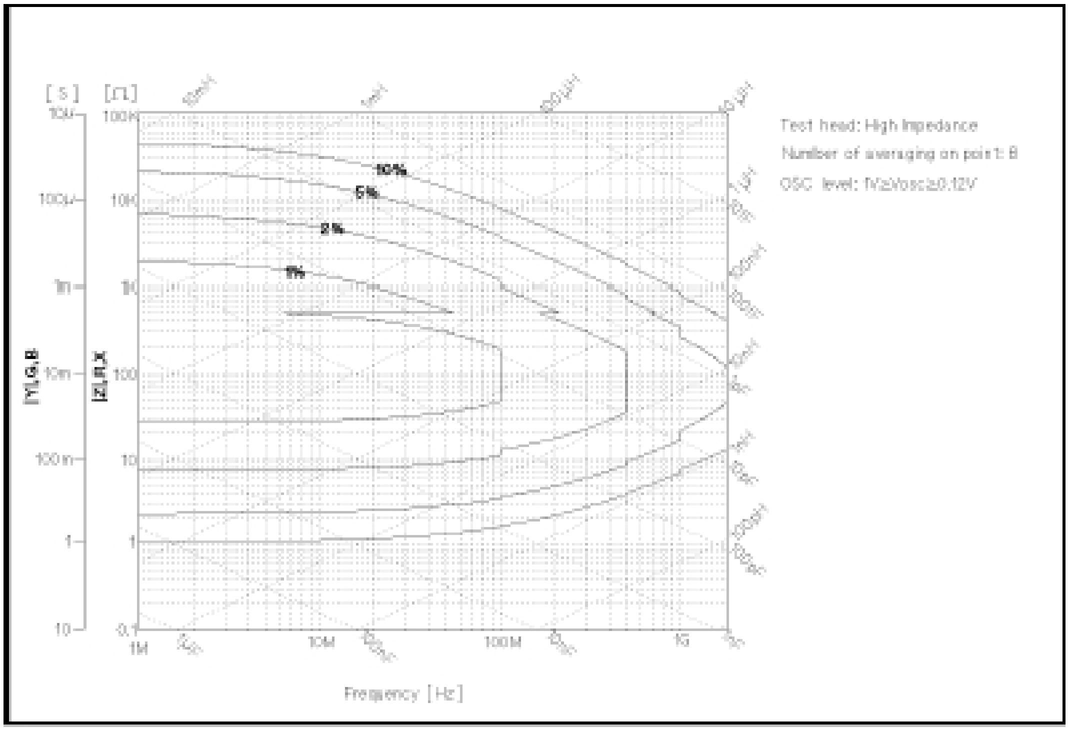

Figure 1-4. Impedance Measurement Accuracy Using High Impedance Test Head (@ High OSC Level)

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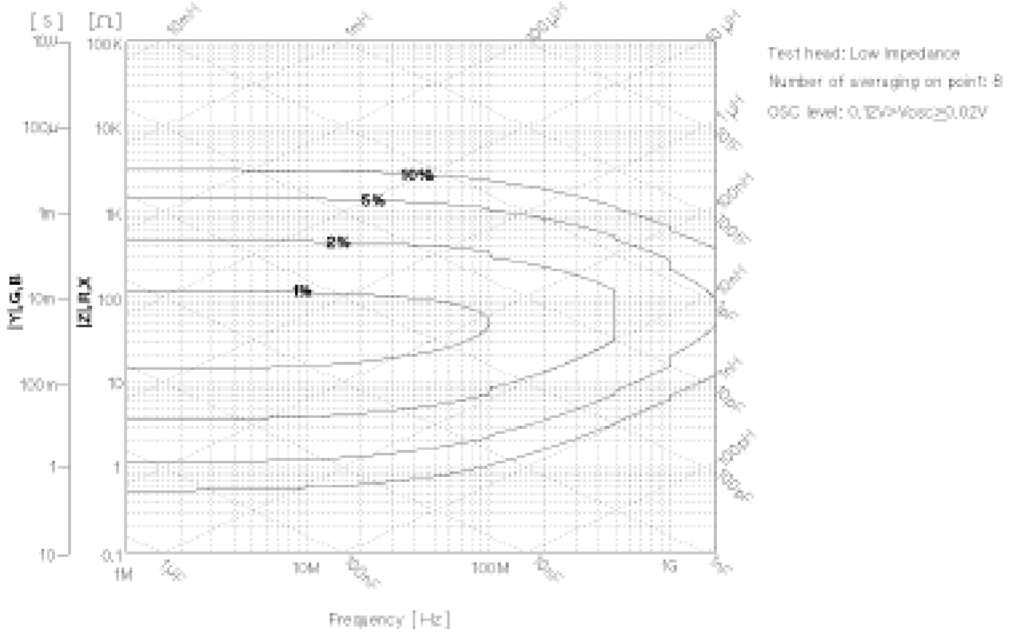

Figure 1-5. Impedance Measurement Accuracy Using Low Impedance Test Head (@ Low OSC Level)

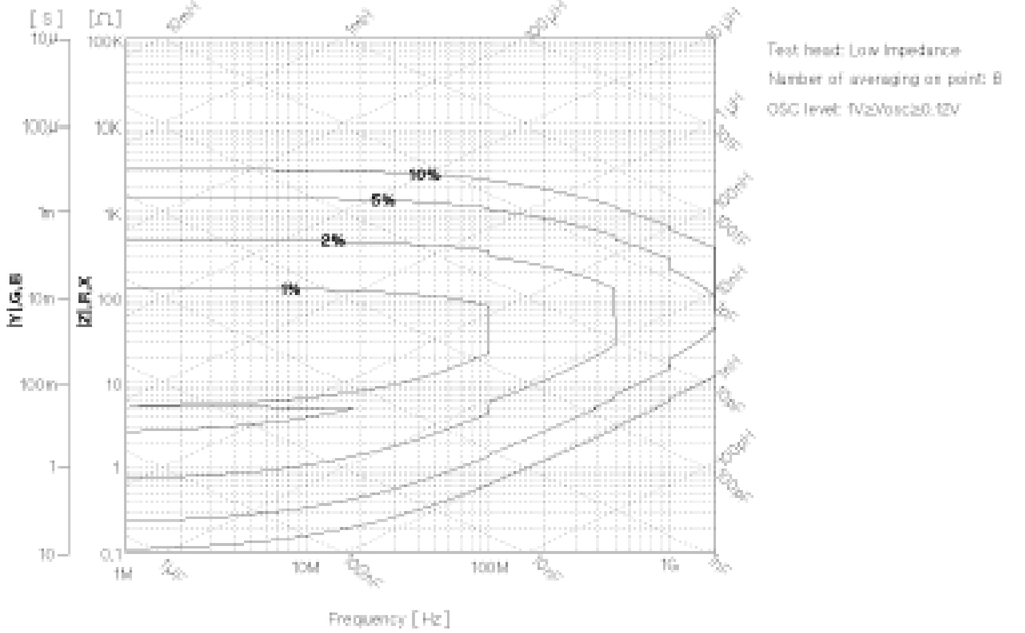

Figure 1-6. Impedance Measurement Accuracy Using Low Impedance Test Head (@ High OSC Level)

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Typical measurement accuracy when open/short/50 Ω/low-loss-capaciter calibration is done

Conditions

- Averaging on point factor is larger than 32 at which calibration is done.
- Cal Points is set to USER DEF.
- Environmental temperature is within ±5°C of temperature at which calibration is done, and within 13°C to 33°C. Beyond this environmental temperature condition, accuracy is twice as bad as specified.

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

θ Accuracy . . . . $\pm \frac{E_c}{100}$ [rad]

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

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

D Accuracy

@ $|D_x \tan(E_c/100)| < 1$ . . . . $\pm\frac{(1 + D_x^2)\tan(E_c/100)}{1 \mp D_x \tan(E_c/100)}$

Especially, $D_x \leq 0.1$ . . . . $\pm\frac{E_c}{100}$

Q Accuracy

@ $|Q_x \tan(E_c/100)| < 1$ . . . . $\pm\frac{(1 + Q_x^2)\tan(E_c/100)}{1 \mp Q_x \tan(E_c/100)}$

Especially, $\frac{10}{E_c} \geq Q_x \geq 10$ . . . . $\pm Q_x^2 \frac{E_c}{100}$

Where,

D_X : Actual D value of DUT

E_a, E_b : are as same as E_a and E_b of the measurement accuracy when OPEN/SHORT/50 Ω calbration is done.

E_c $= 0.06 + 0.14 \times \frac{F}{1800}$ (Typical)

F : measurement frequency [MHz]

Q_x : Actual Q value of DUT

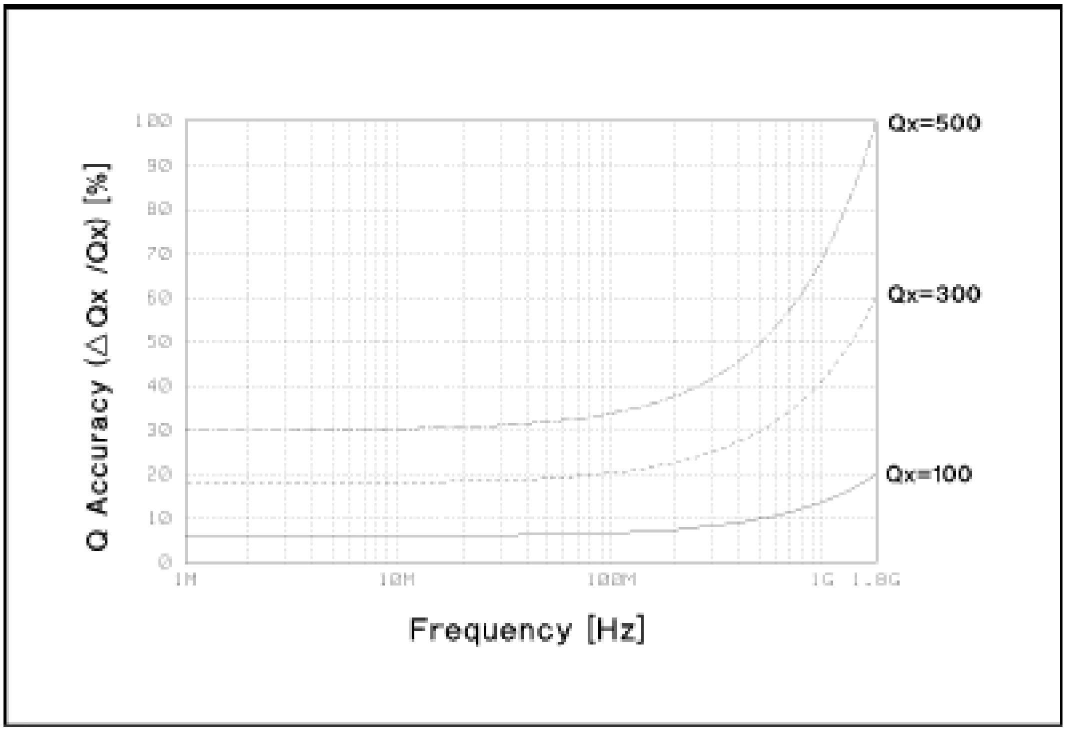


Figure 1-7. Typical measurement accuracy when open/short/50 Ω/low-loss-capaciter calibration is done

Options 013 and 014 High Temperature Test Heads

Specification for Option 013 and 014 High Temperature Test Heads

Frequency Characteristics

Operating frequency . . . . 1 MHz to 1.8 GHz

Source Characteristics

OSC level

Voltage Range

@ 1 MHz $\leq$ Frequency < 1 GHz . . . . $0.2\ mV_{rms}$ to $500\ mV_{rms}$

@ 1 GHz $\leq$ Frequency $\leq$ 1.8 GHz . . . . $0.2\ mV_{rms}$ $250\ mV_{rms}$

OSC level resolution

AC voltage resolution

@ $110\ mV_{rms} < V_{OSC} \leq 500\ mV_{rms}$ . . . . 2 mV

@ $11\ mV_{rms} < V_{OSC} \leq 110\ mV_{rms}$ . . . . 0.2 mV

@ $1.1\ mV_{rms} < V_{OSC} \leq 11\ mV_{rms}$ . . . . 20 μV

@ $0.2\ mV_{rms} \leq V_{OSC} \leq 1.1\ mV_{rms}$ . . . . 2 μV

AC current resolution

@ $2.75\ mA_{rms} < I_{OSC} \leq 12.5\ mA_{rms}$ . . . . 50 μA

@ $0.275\ mA_{rms} < I_{OSC} \leq 2.75\ mA_{rms}$ . . . . 5 μA

@ $27.5\ \mu A_{rms} < I_{OSC} \leq 275\ \mu A_{rms}$ . . . . 0.5 μA

@ $5\ \mu A \leq I_{OSC} \leq 27.5\ \mu A$ . . . . 0.05 μA

AC power resolution

@ $-66.1\ dBm \leq P_{OSC} \leq 1.9\ dBm$ . . . . 0.2 dBm max

OSC level accuracy

@ 1 MHz $\leq$ Frequency $\leq$ 1 GHz, $V_{OSC} \leq 0.25\ V_{rms}$ ($I_{OSC} \leq 6.3$ mA, $P_{OSC} \leq -4.1$ dBm)

. . . . $A + B + \dfrac{8[_{dB}] \times \text{frequency}[_{MHz}]}{1800}$ dB

Where,

A depends on temperature conditions as follows:

within referenced to 23±5°C . . . . 4 dB

@ 0°C to 18°C, 28°C to 40°C . . . . 6 dB

B depends on OSC level as follows:

@ $0.5\ V_{rms} \geq V_{OSC} \geq 120\ mV_{rms}$ . . . . 0 dB
($12.5\ mA_{rms} \geq I_{OSC} \geq 3 mA_{rms}$)
($1.9\ dBm \geq P_{OSC} \geq -10\ dBm$)

@ $120\ mV_{rms} > V_{OSC} \geq 1.2\ mV_{rms}$ . . . . 1 dB
($3\ mA_{rms} > I_{OSC} \geq 30\ \mu A_{rms}$)
($-10\ dBm > P_{OSC} \geq -50\ dBm$)

@ $1.2\ mV_{rms} > V_{OSC} \geq 0.2\ mV_{rms}$ . . . . 2 dB
($30\ \mu A_{rms} > I_{OSC} \geq 5\ \mu A_{rms}$)
($-50\ dBm > P_{OSC} \geq -66.1\ dBm$)

Output impedance . . . . 40 Ω (Nominal value)

Level Monitor

Monitor accuracy

OSC level . . . . Same as OSC level accuracy (typical)

DC bias . . . . Twice as bad as specifications of dc level accuracy (typical)

Options 013 and 014 High Temperature Test Heads

Basic Measurement Accuracy

Conditions of accuracy specifications

- OPEN/SHORT/50 Ω calibration must be done. Calibration ON.
- Averaging (on point) factor must be larger than 32 at which calibration is done.
- Measurement points are same as the calibration points.
- Environmental temperature is within ±5°C of temperature at which calibration is done, and within 13°C to 33°C. Beyond this environmental temperature condition, and within 0°C to 40°C, accuracy is twice as bad as specified.
- Bending cable should be smooth and the bending angle is less than 30°.
- Cable position should be kept in the same position after calibration measurement.
- OSC level must be same as level at which calibration is done.
- OSC level is less than or equal to 0.25 V, or OSC level is greater than 0.25 V and frequency range is within 1 MHz to 1 GHz.

|Z| Accuracy . . . . $\pm(E_a + E_b)$ [%]

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

Where,

E_a: depends on measurement frequency as follows:

@ 1 MHz ≤ frequency ≤ 100 MHz . . . . 0.6 [%]

@ 100 MHz < frequency ≤ 500 MHz . . . . 0.8 [%]

@ 500 MHz < frequency ≤ 1 GHz . . . . 1.5 [%]

@ 1 GHz < frequency ≤ 1.8 GHz . . . . 3.0 [%]

E_b = $(Z_s/Z_x + Y_oZ_x) \times 100$ [%]

Z_s and **Y_o** depend on number of point averaging (N_{av}) and OSC level (V_{osc}) as follows:

Z_x: Impedance measurement value [Ω]

Options 013 and 014 High Temperature Test Heads

Table 1-3. Z_s and Y_o When High Impedance Test Head Is Used

Measurement Conditions			
Number of Point Averaging (N_{av})	OSC Signal Level (V_{osc})[1]	Z_S [Ω]	Y_o [S]
$1 \le N_{av} \le 7$	$V_{osc} < 0.02$	$\frac{0.02}{V_{osc}} \times (0.2 + 0.001 \times f_{[MHz]})$	$\frac{0.02}{V_{osc}} \times (5 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]})$
	$0.02V \le V_{osc} < 0.12$	$0.2 + 0.001 \times f_{[MHz]}$	$5 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]}$
	$0.12V \le V_{osc}$	$0.2 + 0.001 \times f_{[MHz]}$	$3 \times 10^{-6} + 2 \times 10^{-7} \times f_{[MHz]}$
$8 < N_{av}$	$V_{osc} < 0.02$	$\frac{0.02}{V_{osc}} \times (0.1 + 0.001 \times f_{[MHz]})$	$\frac{0.02}{V_{osc}} \times (2 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]})$
	$0.02V \le V_{osc} < 0.12$	$0.1 + 0.001 \times f_{[MHz]}$	$2 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]}$
	$0.12V \le V_{osc}$	$0.1 + 0.001 \times f_{[MHz]}$	$2 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]}$

1. $V_{osc} = 0.12V \equiv I_{osc} = 3$ mA $\equiv P_{OSC} = -10$ dBm, $V_{osc} = 0.02V \equiv I_{osc} = 0.5$ mA $\equiv P_{osc} = -26$ dBm

Table 1-4. Z_s and Y_o When Low Impedance Test Head Is Used

Measurement Conditions			
Number of Point Averaging (N_{av})	OSC Signal Level (V_{osc})[1]	Z_S [Ω]	Y_o [S]
$1 \le N_{av} \le 7$	$V_{osc} < 0.02$	$\frac{0.02}{V_{osc}} \times (0.1 + 0.001 \times f_{[MHz]})$	$\frac{0.02}{V_{osc}} \times (1 \times 10^{-4} + 2 \times 10^{-7} \times f_{[MHz]})$
	$0.02V \le V_{osc} < 0.12$	$0.1 + 0.001 \times f_{[MHz]}$	$1 \times 10^{-4} + 2 \times 10^{-7} \times f_{[MHz]}$
	$0.12V \le V_{osc}$	$0.05 + 0.001 \times f_{[MHz]}$	$1 \times 10^{-4} + 2 \times 10^{-7} \times f_{[MHz]}$
$8 < N_{av}$	$V_{osc} < 0.02$	$\frac{0.02}{V_{osc}} \times (0.05 + 0.001 \times f_{[MHz]})$	$\frac{0.02}{V_{osc}} \times (3 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]})$
	$0.02V \le V_{osc} < 0.12$	$0.05 + 0.001 \times f_{[MHz]}$	$3 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]}$
	$0.12V \le V_{osc}$	$0.03 + 0.001 \times f_{[MHz]}$	$3 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]}$

1. $V_{osc} = 0.12V \equiv I_{osc} = 3$ mA $\equiv P_{OSC} = -10$ dBm, $V_{osc} = 0.02V \equiv I_{osc} = 0.5$ mA $\equiv P_{osc} = -26$ dBm

At the following frequency points, instrument spurious characteristics could occasionally cause measurement errors to exceed specified value because of instrument spurious characteristics.

10.71 MHz	17.24 MHz	21.42 MHz	42.84 MHz
514.645 MHz	686.19333 MHz	1029.29 MHz	1327.38666 MHz

See “EMC” under “Others” in “General Characteristics.”
The excessive vibration and shock could occasionally cause measurement errors to exceed specified values.

Options 013 and 014 High Temperature Test Heads

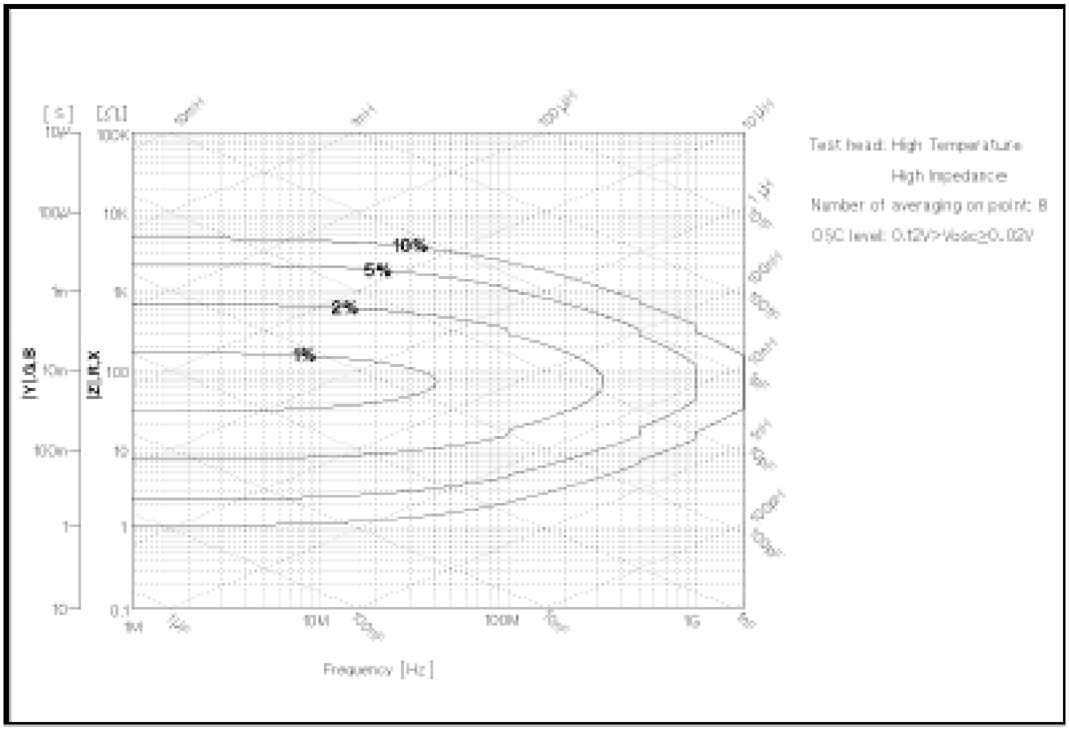


Figure 1-8. Impedance Measurement Accuracy Using High Temperature High Impedance Test Head (@ Low OSC Level)

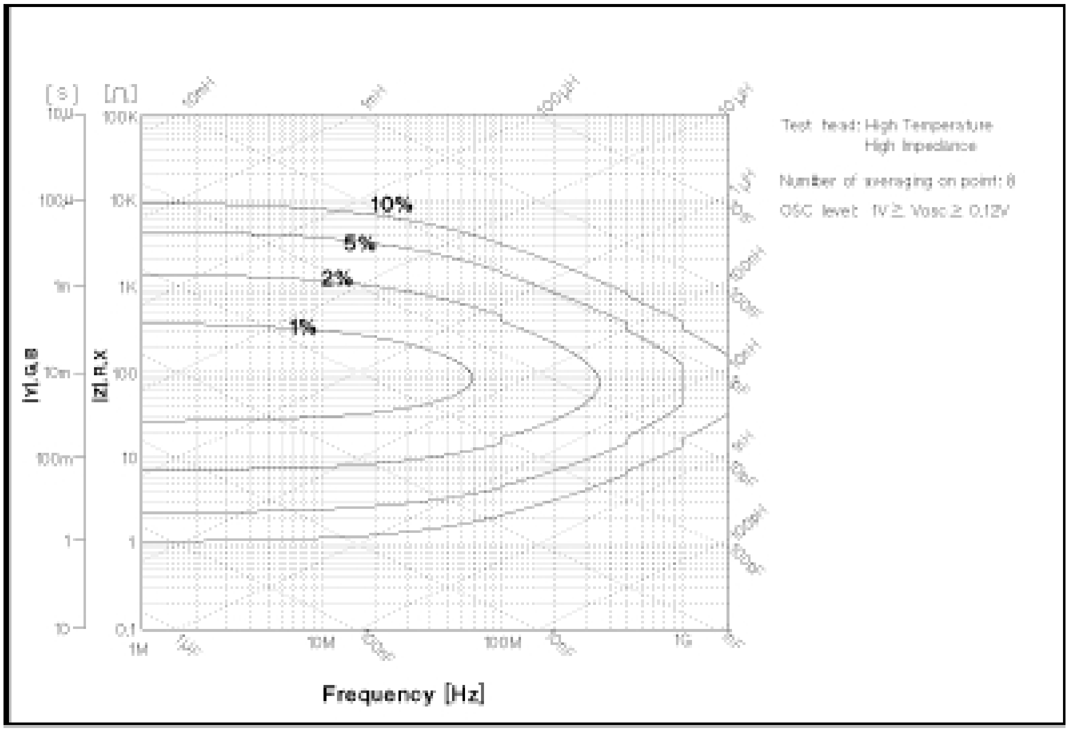


Figure 1-9. Impedance Measurement Accuracy Using High Temperature High Impedance Test Head (@ High OSC Level)

Options 013 and 014 High Temperature Test Heads

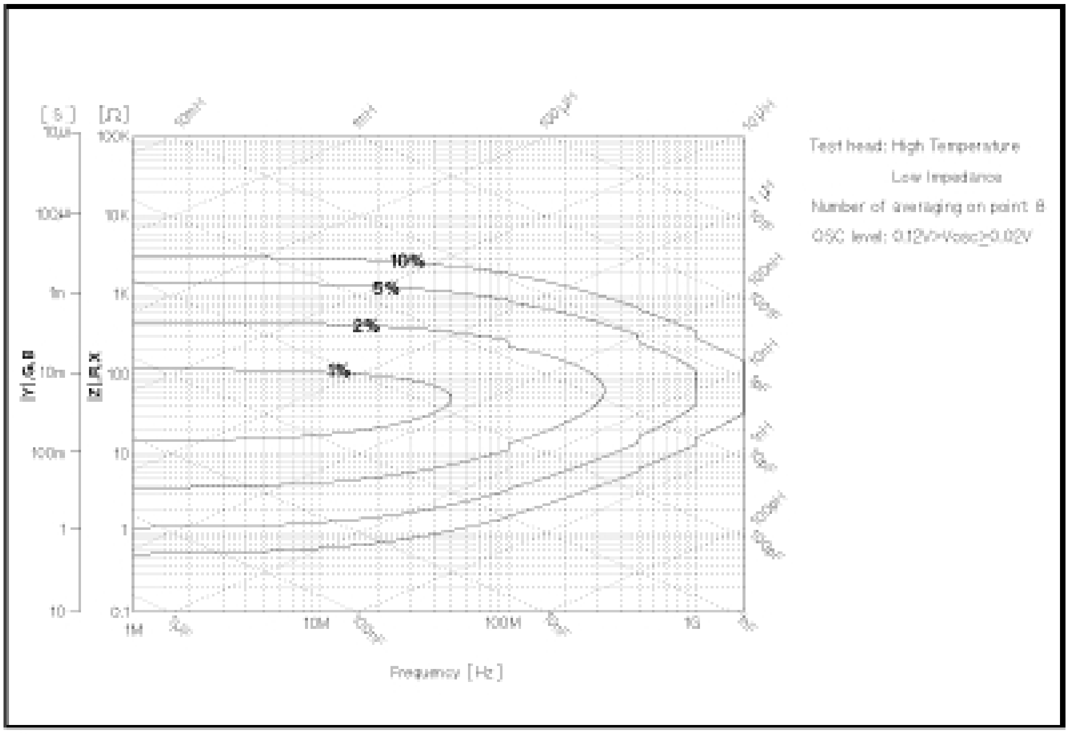


Figure 1-10. Impedance Measurement Accuracy Using High Temperature Low Impedance Test Head (@ Low OSC Level)

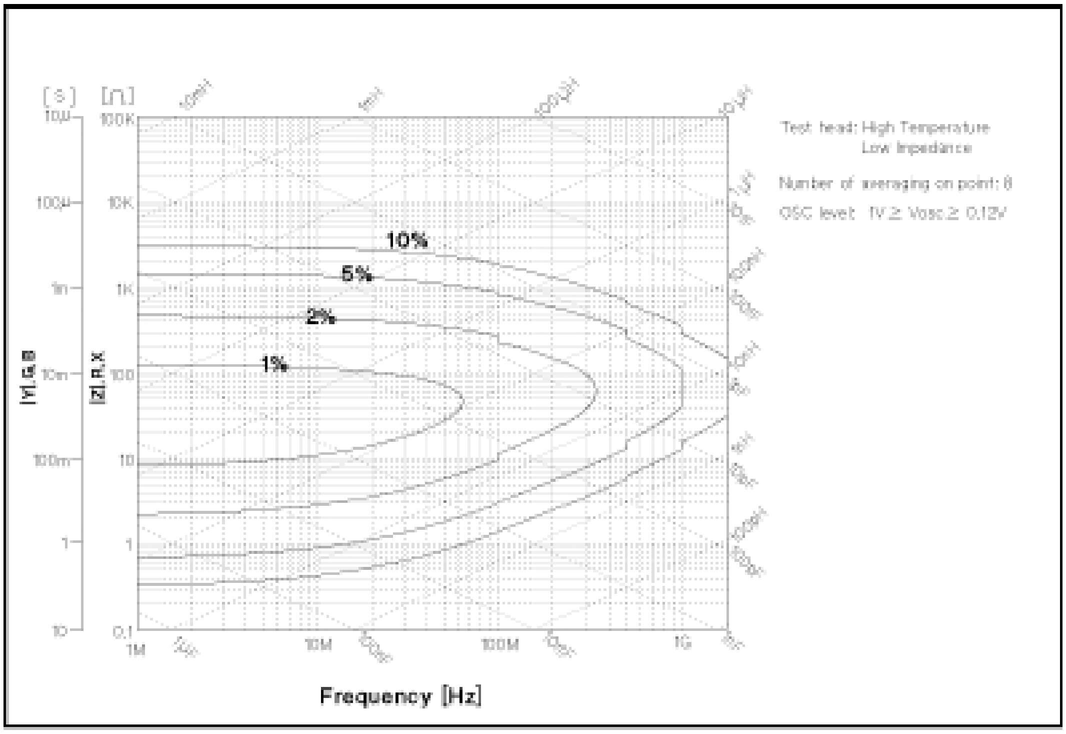


Figure 1-11. Impedance Measurement Accuracy Using High Temperature Low Impedance Test Head (@ High OSC Level)

Options 013 and 014 High Temperature Test Heads

Typical Effects of Temperature Drift on Measurement Accuracy

When environmental temperature exceeds ±5°C of temperature at which calibration is done, add the following measurement error.

Conditions of typical effects of temperature drift

- Environment temperature of a test head is within –55°C to 0°C or 40°C to 200°C.
- Environment temperature of the mainframe is within ±5°C of temperature at which calibration is done, and within 0°C to 40°C.
- Other conditions are as same as the conditions of the basic measurement accuracy of Option 013/014.

|Z| Accuracy . . . . $\pm(E_{a2} + E_{b2})$ [%]

θ Accuracy . . . . $\pm \dfrac{(E_{a2} + E_{b2})}{100}$ [rad]

Where,

E_{a2} $= (\Delta A_1 \Delta T + \Delta A_2) \times 10^8$
E_{b2} $= (Z_{s2}/Z_x + Y_{o2}Z_x) \times 100$

ΔA_1 is the effect of temperature drift on the impedance measurement value as follows:
$(50 + 300 \times f)$ [ppm/°C] (typical)
ΔA_2 is the hysterisiss of the effect of temperature drift on the impedance measurement value as follows:

$\dfrac{\Delta A_1 \Delta T}{3}$ [ppm] (typical)

f : Measurement Frequency [GHz]
ΔT: Difference of temperature between measurement condition and calibration measurement condition. [°C]
Y_{o2} $= (\Delta Y_{o1} \Delta T + \Delta Y_{o2}) \times 10^{-6}$ [S]
Z_{s2} $= (\Delta Z_{s1} \Delta T + \Delta Z_{s2}) \times 10^{-3}$ [Ω]
Z_x: Impedance measurement value [Ω]
Y_{o1} is the temperature coefficient for OPEN residual as follows:
@ High Temperature High Impedance Test Head is used . . . . $(0.2 + 8 \times f^2)$ [μS/°C] (typical)
@ High Temperature Low Impedance Test Head is used . . . . $(1 + 30 \times f)$ [μS/°C] (typical)

Y_{o2} is the hysterisis of the OPEN residual as follows: . . . . $\dfrac{\Delta Y_{01} \Delta T}{3}$ [μS/°C](typical)

ΔZ_{s1} is the temperature coefficient for SHORT residual as follows:
@ High Temperature High Impedance Test Head is used . . . . $(4 + 50 \times f)$ [mΩ°C] (typical)
@ High Temperature Low Impedance Test Head is used . . . . $(1 + 10 \times f^2)$ [mΩ°C] (typical)

ΔZ_{s2} is the hysterisis of the SHORT residual as follows: . . . . $\dfrac{\Delta Z_{s1} \Delta T}{3}$ [mΩ/°C](typical)

Options 013 and 014 High Temperature Test Heads

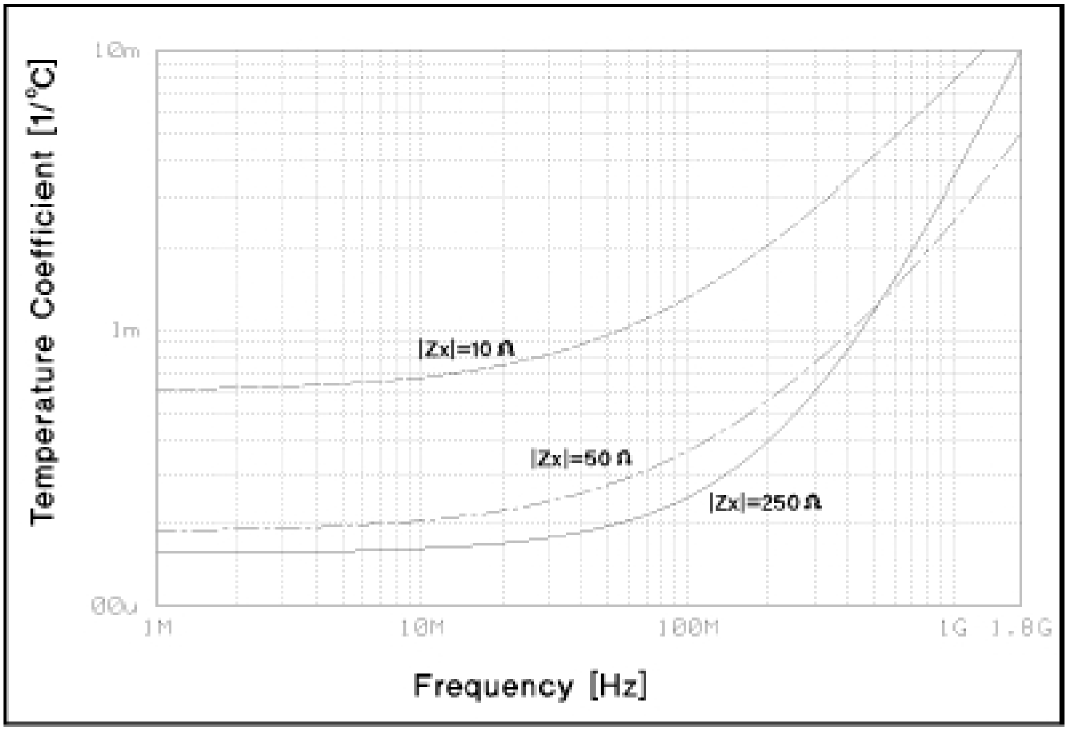


Figure 1-12. Typical Frequency Characteristics of Temperature Coefficient Using High Temperature High Impedance Test Head

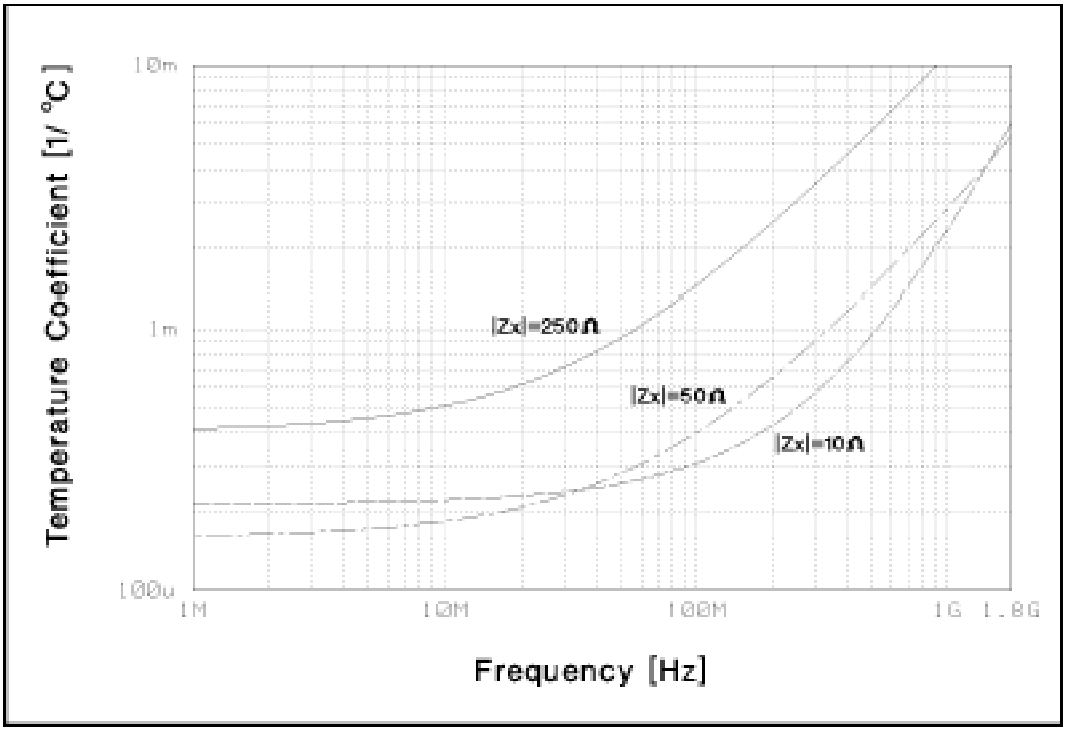


Figure 1-13. Typical Frequency Characteristics of Temperature Coefficient Using High Temperature Low Impedance Test Head

Options 013 and 014 High Temperature Test Heads

Operation Conditions of the Test Head

- The cable must be at the same temperature as the main frame at least 15 cm from the test station.
  . . . . 55°C to +200°C

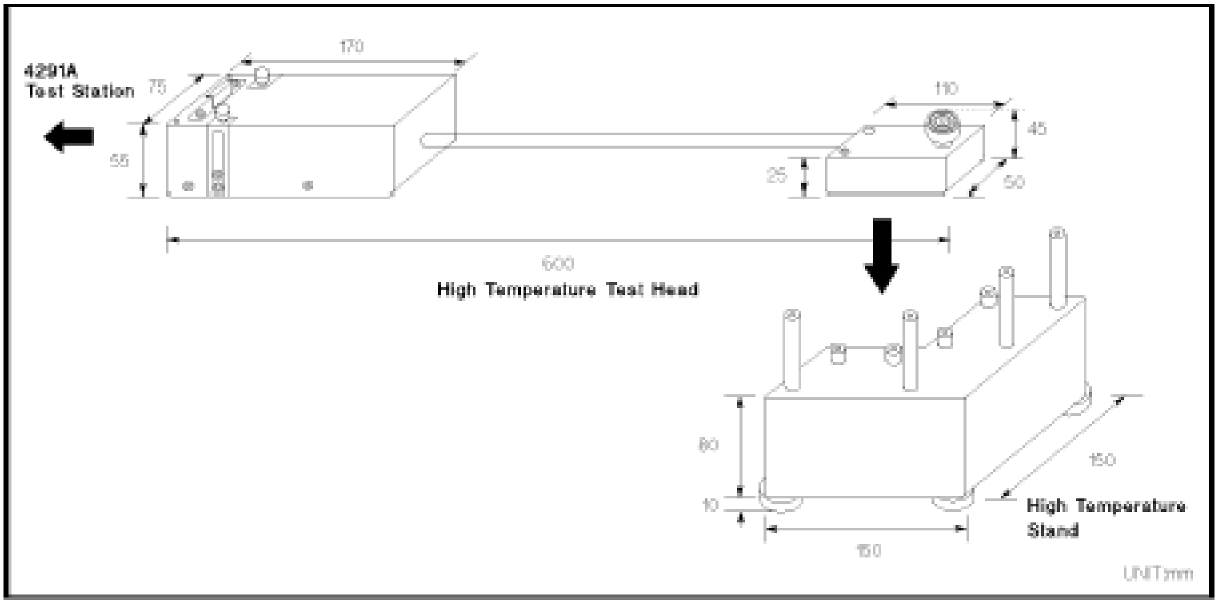


Figure 1-14. Dimensions of High Temperature Test Head

Options 013 and 014 High Temperature Test Heads

Display

LCD	
Type/size	Color TFT, 8.4 inch
Resolution	640 × 480
Effective Display Area	160 mm × 115 mm (600 × 430 dots)
Number of display channels	2
Format	single, dual split or overwrite, graphic, and tabular
Number of traces	
For measurement	1 trace/channel
For memory	16 traces/channel (maximum)
Data math functions	gain × data-offset gain × memory – offset gain × (data – memory) – offset gain × (data + memory) – offset gain × (data/memory) – offset gain × (data × memory) – offset
Marker	
Number of markers	
Main marker	1 for each channel
Sub-marker	7 for each channel
∆Marker	1 for each channel

Data Storage

Type	floppy disk drive, Volatile memory disk
Capacity	
floppy disk	720 kB/1.44 MB
Volatile memory disk, can be backed up by flash memory	448 kB (maximum)
Disk format	LIF, DOS

GPIB

Interface	IEEE 488.1-1987, IEC625
Interface function	SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PPO, DC1, DT1, C1, C2, C3, C4, C11, E2
Numeric Data Transfer formats	ASCII 32 and 64 bit IEEE 754 Floating point format, DOS PC format (32 bit IEEE with byte order reversed)
Protocol	IEEE 488.2-1987

Options 013 and 014 High Temperature Test Heads

Printer Parallel Port

Interface	IEEE 1284 Centronics standard compliant
Printer control language	HP PCL3 Printer Control Language
Connector	D-sub (25-pin)

General Characteristics

Input and Output Characteristics

External reference input

Frequency	10 MHz ±100 Hz (typically)
Level	> –6 dBm (typically)
Input impedance	50 Ω (nominal)
Connector	BNC female

Internal Reference Output

Frequency	10 MHz (nominal)
Level	2 dBm (typically)
Output impedance	50 Ω (nominal)
Connector	BNC female

External trigger input

Level	TTL Level
Pulse width (Tp)	> 2μs (typically)
Polarity	positive/negative selective
Connector	BNC female

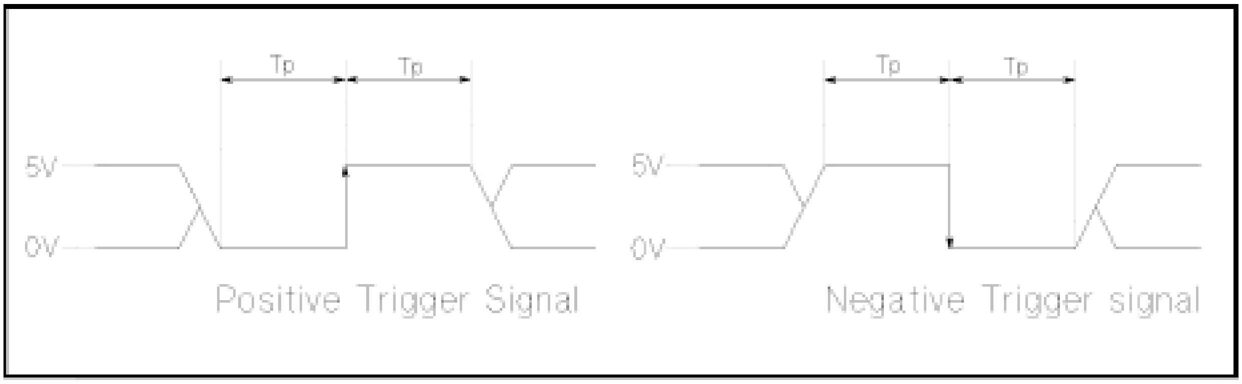


Figure 1-15. Trigger Signal

External monitor output

Connector	D-sub (15-pin HD)
Display resolution	640 × 480 VGA

Options 013 and 014 High Temperature Test Heads

Operation Conditions

Temperature	
Disk drive non-operating condition	0°C to 40°C
Disk drive operating condition	10°C to 40°C
Humidity	
@ wet bulb temperature <29°C, without condensation	
Disk drive non-operating condition	15 % to 95 % RH
Disk drive operating condition	15 % to 80 % RH
Altitude	0 to 2,000 meters
Warm-up time	30 minutes

Non-operation conditions

Temperature	–20°C to 60°C
Humidity	
@ wet bulb temperature <45°C, without condensation	15 % to 95 % RH
Altitude	0 to 4,572 meters

Others

EMC	Complies with CISPR 11 (1990) / EN 55011 (1991) : Group 1, Class A
	Complies with IEC 1000-3-2 (1995) / EN 61000-3-2 (1995)
	Complies with IEC 1000-3-3 (1994) / EN 61000-3-3 (1995)
	Complies with IEC 1000-4-2 (1995) / EN 50082-1 (1992) : 4 kV CD, 8 kV AD
	Complies with IEC 1000-4-2 (1995) / EN 50082-1 (1992) : 3 V/m
	Complies with IEC 1000-4-4 (1995) / EN 50082-1 (1992) : 1 kV / Main, 0.5k V / Signal Line

Note: When tested at 3 V/m according to IEC 1000-4-3 (1995), the measurement accuracy will be within specifications over the full immunity test frequency range of 27 to 1000 MHz except when the analyzer frequency is identical to the transmitted interference signal test frequency.

Safety	Complies with IEC 1010-1 (1990), Amendment 1 (1992) and Amendment 2 (1995).
	Complies with CSA-C22.2 No. 1010.1-92.
Power requirements	90V to 132V, or 198V to 264V (automatically switched), 47 to 63 Hz, 300VA max

Weight	
Mainframe	21.5 kg (SPC)
Test Station	3.7 kg
Dimensions	
Mainframe	425 (W) × 235 (H) × 553 (D) mm
Test Station	275 (W) × 95 (H) × 205 (D) mm

Options 013 and 014 High Temperature Test Heads

External Program Run/Cont Input

Connector	BNC female
Level	TTL
Keyboard connector	mini-DIN
I/O port	4 bit in/ 8 bit out port, TTL Level

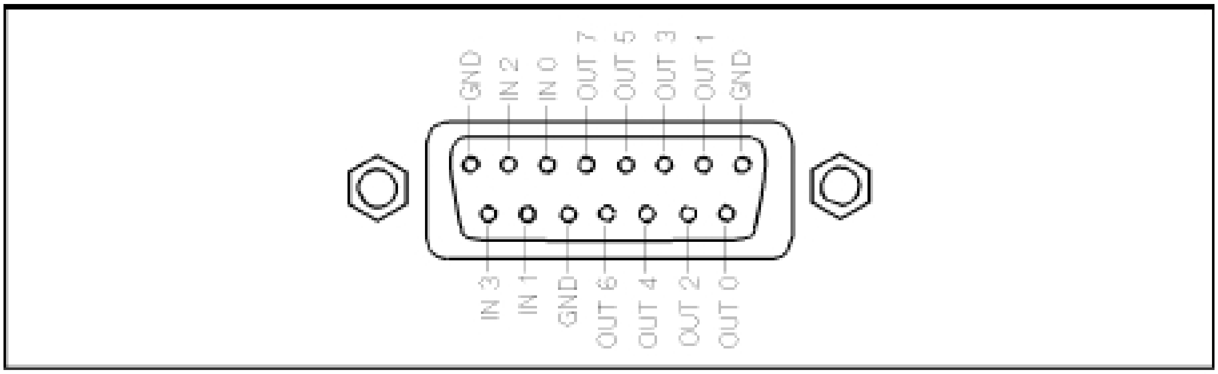


Figure 1-16. I/O Port Pin Assignment

Specifications for Option 1D5 High Stability Frequency Reference

Reference Oven Output

Frequency	10 MHz (nominal)
Level	0 dBm (typically)
Output Impedance	50 Ω (nominal)
Connector	BNC female

Option 002 Material Measurement

Supplemental Characteristics for Option 002 Material Measurement

Measurement Frequency Range

Using the Agilent 16453A	1 MHz to 1.0 GHz (Typical)
Using the Agilent 16454A	1 MHz to 1.0 GHz (Typical)

Measurement Parameters

Permittivity parameters	$\lvert\varepsilon_r\rvert$, ε_r', ε_r'', tanδ
Permeability parameters	$\lvert\mu_r\rvert$, μ_r', μ_r'', tanδ

Typical Measurement Accuracy

Conditions of accuracy characteristics

- Use the High Z Test Head for permittivity measurement
- Use the Low Z Test Head for permeability measurement
- OPEN/SHORT/50 Ω calibration must be done. Calibration ON.
- Averaging (on point) factor is larger than 32 at which calibration is done if Cal points is set to USER DEF.
- Measurement points are same as the calibration points if Cal point is set to USER DEF.
- Environment temperature is within ±5°C of temperature at which calibration is done, and within 13°C to 33°C. Beyond this environmental temperature condition, accuracy is twice as bad as specified.

ε_r' Accuracy $\left(\frac{\Delta\varepsilon'_{rm}}{\varepsilon'_{rm}}\right)$

@ tanδ < 0.1. . . . . $5 + \left(10 + \frac{0.04}{f}\right)\frac{t}{\varepsilon'_{rm}} + 0.25\frac{\varepsilon'_{rm}}{t} + \frac{100}{\lvert 1 - (13/\sqrt{\varepsilon'_{rm}}/f)^2\rvert}$ [%] (Typical)

Loss Tangent Accuracy of $\overset{A}{\varepsilon_r}$ (Δtanδ)

@ tanδ < 0.1 . . . . $E_a + E_b$ (Typical)

Where,

@ frequency ≤ 1 GHz

$$\mathbf{E_a} = 0.002 + \frac{0.0004}{f}\;\frac{t}{\varepsilon'_m} + 0.004f + \frac{0.1}{\lvert 1 - (13/\sqrt{\varepsilon'_{rm}}/f)^2\rvert} \text{ (Typical)}$$

@ frequency > 1 GHz

$$\mathbf{E_a} = 0.002 + \frac{0.0004}{f}\;\frac{t}{\varepsilon'_m} + 0.004f + \frac{0.1}{\lvert 1 - (13/\sqrt{\varepsilon'_{rm}}/f)^2\rvert} \text{ (Typical)}$$

$$\mathbf{E_b} = \left(\frac{\Delta\varepsilon'_{rm}}{\varepsilon'_{rm}}\;\frac{1}{100} + \varepsilon'_{rm}\frac{0.002}{t}\right)\ \tan\delta \text{ (Typical)}$$

f is measurement frequency [GHz]
t is thickness of MUT [mm]
$\varepsilon'_{\mathbf{rm}}$ is measured value of $\varepsilon'_{\mathbf{r}}$
tanδ is measured value of dielectric loss tangent

Option 002 Material Measurement

μ_r' **Accuracy** $\frac{\Delta\mu'_{rm}}{\mu'_{rm}}$

@ tanδ < 0.1 . . . . $4 + \frac{25}{F\mu'_{rm}} + F\mu'_{rm}\left(1 + \frac{15}{F\mu'_{rm}}\right)^2 f^2 [\%]$ (Typical)

Loss Tangent Accuracy of $\hat{\mu}_r$ ($\Delta\tan\delta$)
@ tanδ < 0.1. . . . . $E_a + E_b$ (Typical)

Where,
E_a $= 0.002 + \frac{0.001}{F\mu'_{rm} f} + 0.004 f$ (Typical)

E_b $= \frac{\Delta\mu'_{rm}}{\mu'_{rm}} \frac{\tan\delta}{100}$ (Typical)

f is measurement frequency [GHz]

F $= h \ln \frac{c}{b}$ [mm]

h is the height of MUT [mm]
b is the inner diameter of MUT
c is the outer diameter of MUT
tanδ is the measured value of loss tangent
$\mu'_{rm}$is the measured value of permeability

At the following frequency points, instrument spurious characteristics could occasionally cause measurement errors to exceed specified value.

10.71 MHz 17.24 MHz 21.42 MHz 42.84 MHz
514.645 MHz 686.19333 MHz 1029.29 MHz 1327.38666 MHz

See “EMC” under “Others” in “General Characteristics.”

Option 002 Material Measurement

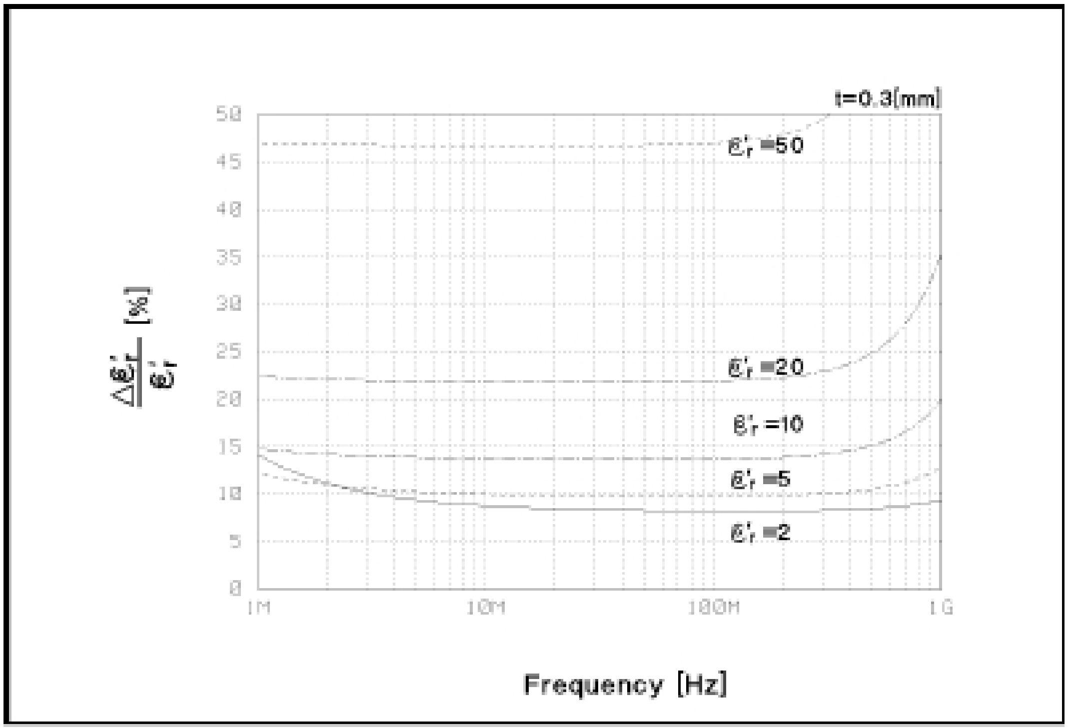


Figure 1-17. Typical Permittivity Measurement Accuracy (@ thickness = 0.3 mm)

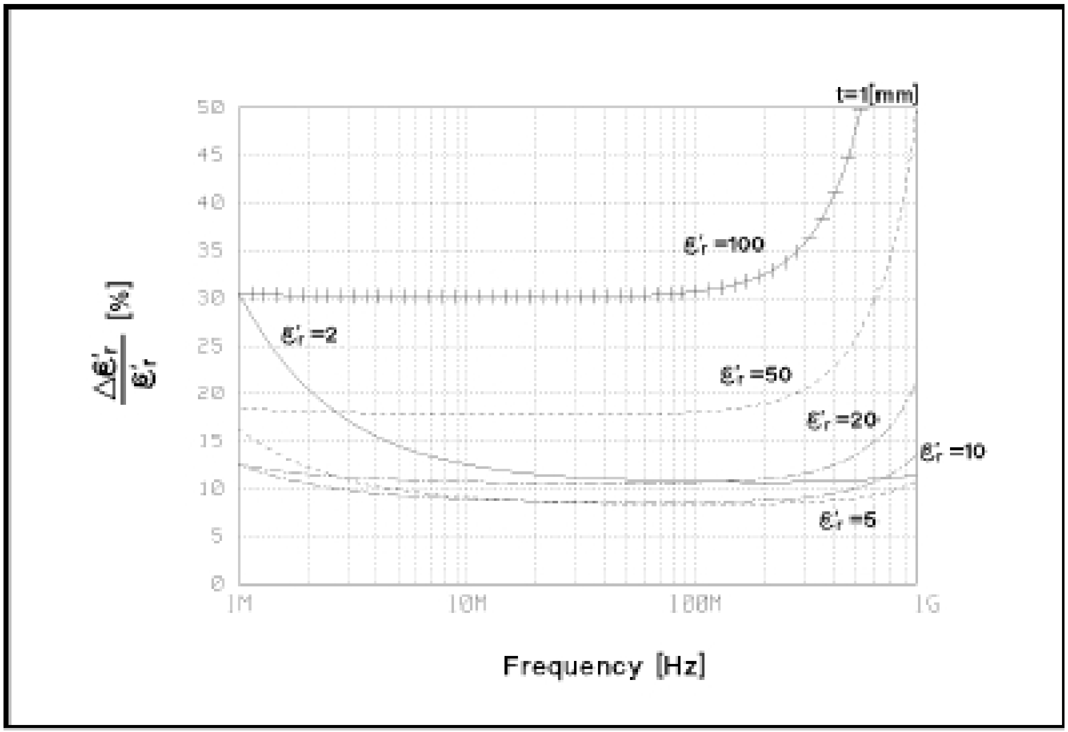


Figure 1-18. Typical Permittivity Measurement Accuracy (@ thickness = 1 mm)

Option 002 Material Measurement

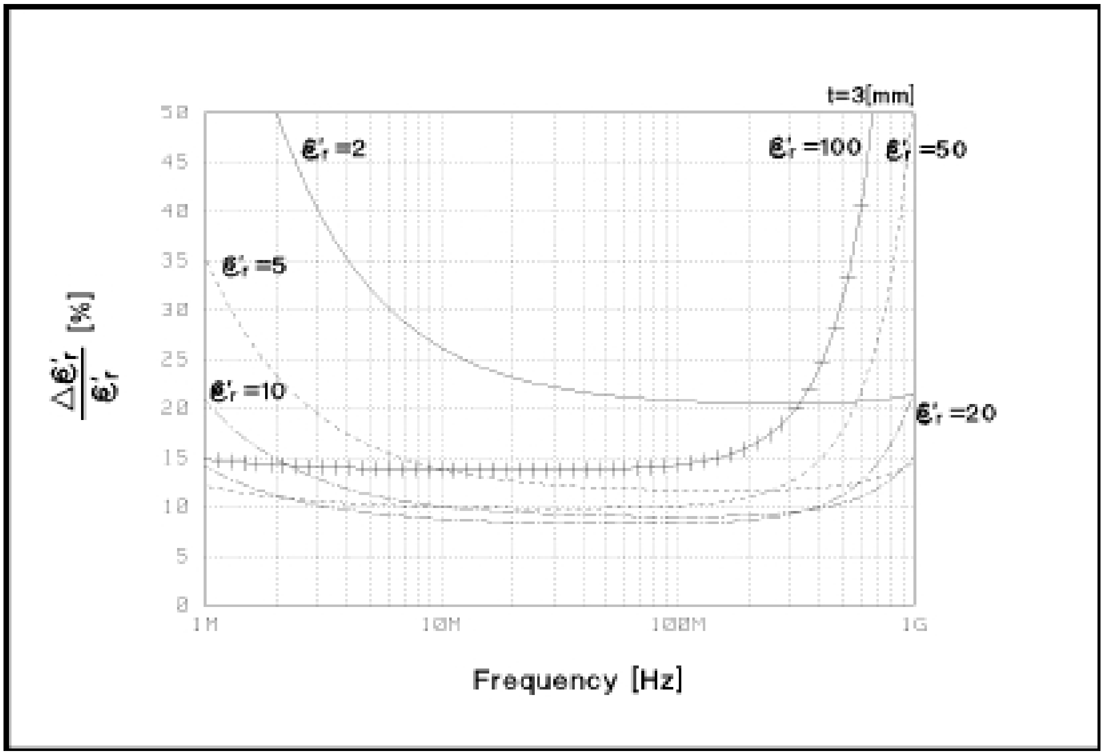


Figure 1-19. Typical Permittivity Measurement Accuracy (@ thickness = 3 mm)

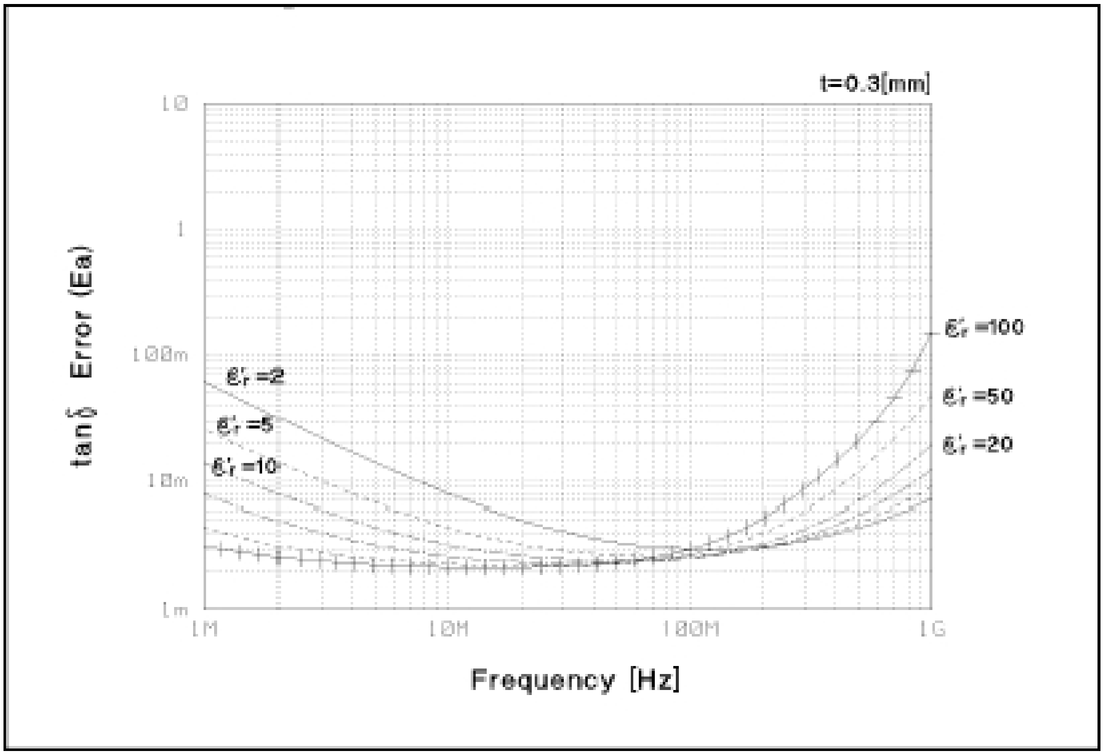


Figure 1-20. Typical Dielectric Loss Tangent (tanδ) Measurement Accuracy (@ thickness = 0.3 mm)

Option 002 Material Measurement

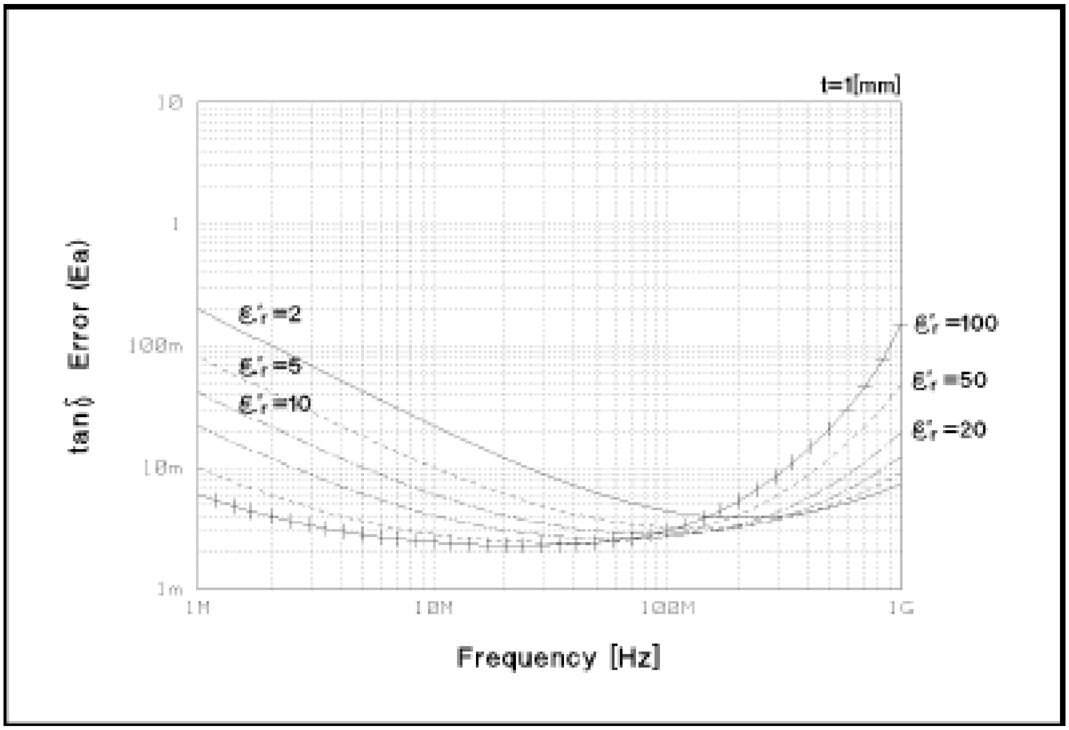


Figure 1-21. Typical Dielectric Loss Tangent (tanδ) Measurement Accuracy (@ thickness = 1 mm)

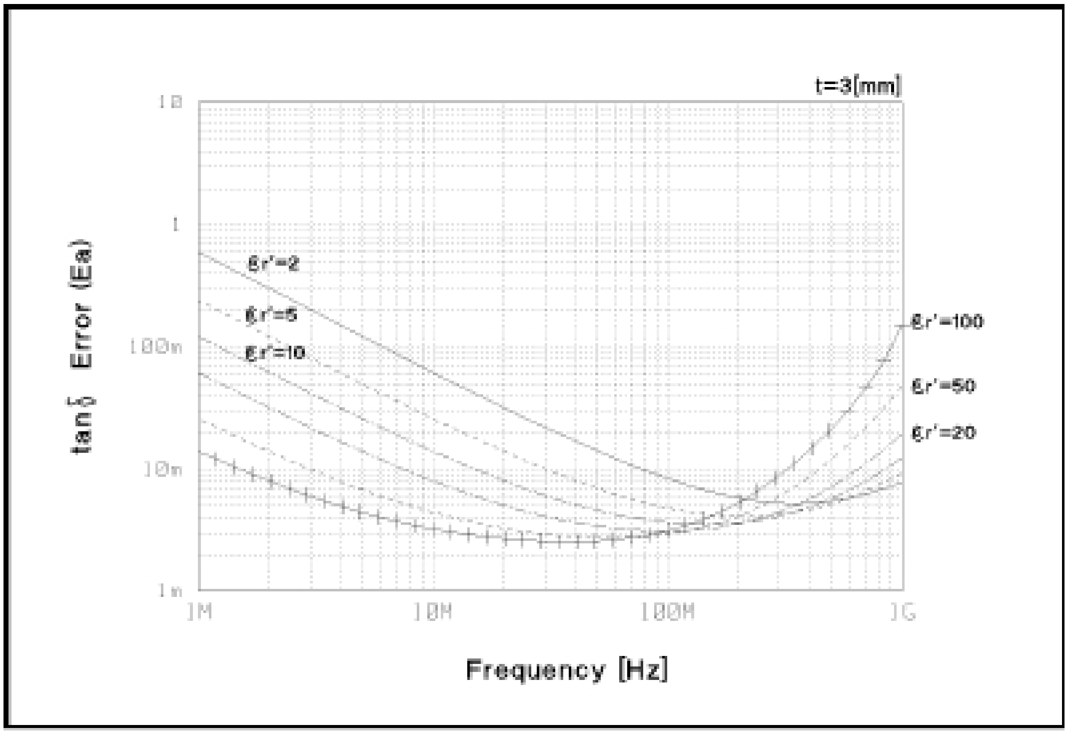


Figure 1-22. Typical Dielectric Loss Tangent (tanδ) Measurement Accuracy (@ thickness = 3 mm)

Option 002 Material Measurement

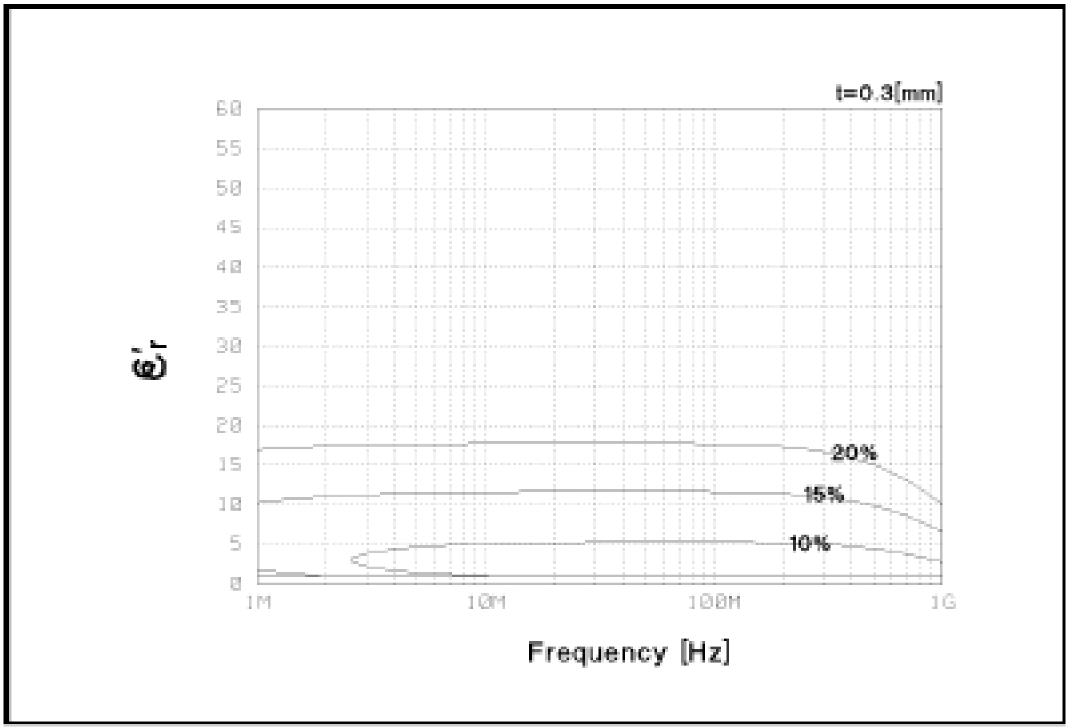


Figure 1-23. Typical Permittivity Measurement Accuracy (ε_r vs. Frequency, @ thickness = 0.3 mm)

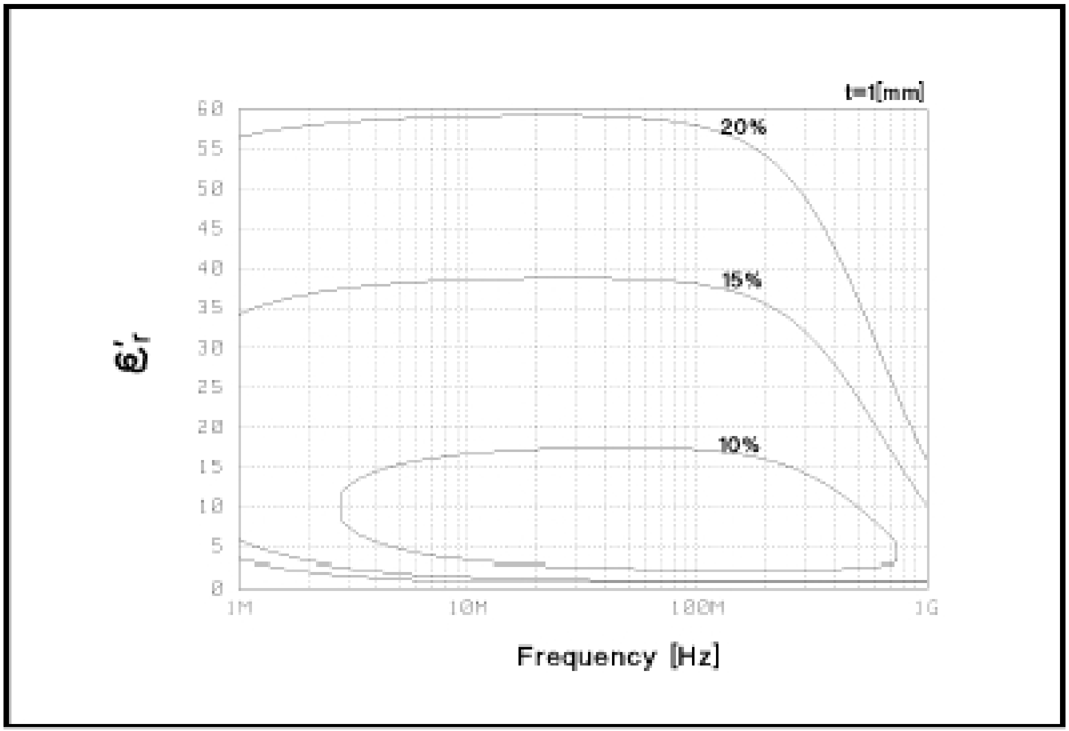


Figure 1-24. Typical Permittivity Measurement Accuracy (ε_r vs. Frequency, @ thickness = 1 mm)

Option 002 Material Measurement

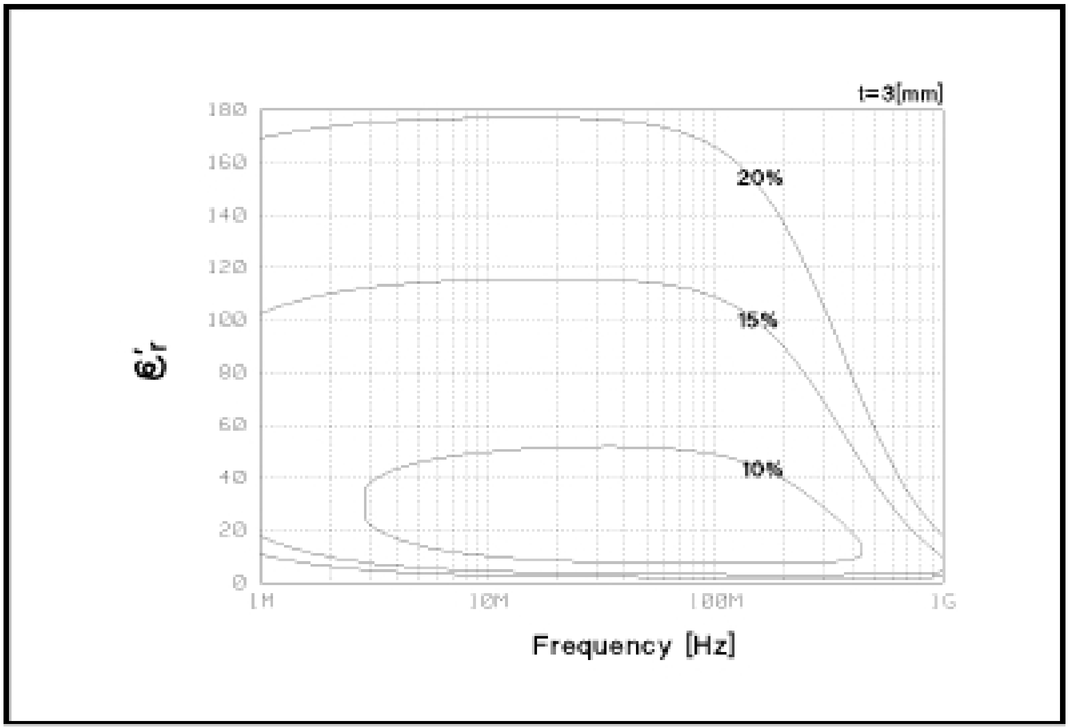


Figure 1-25. Typical Permittivity Measurement Accuracy (ε_r vs. Frequency, @ thickness = 3 mm)

Option 002 Material Measurement

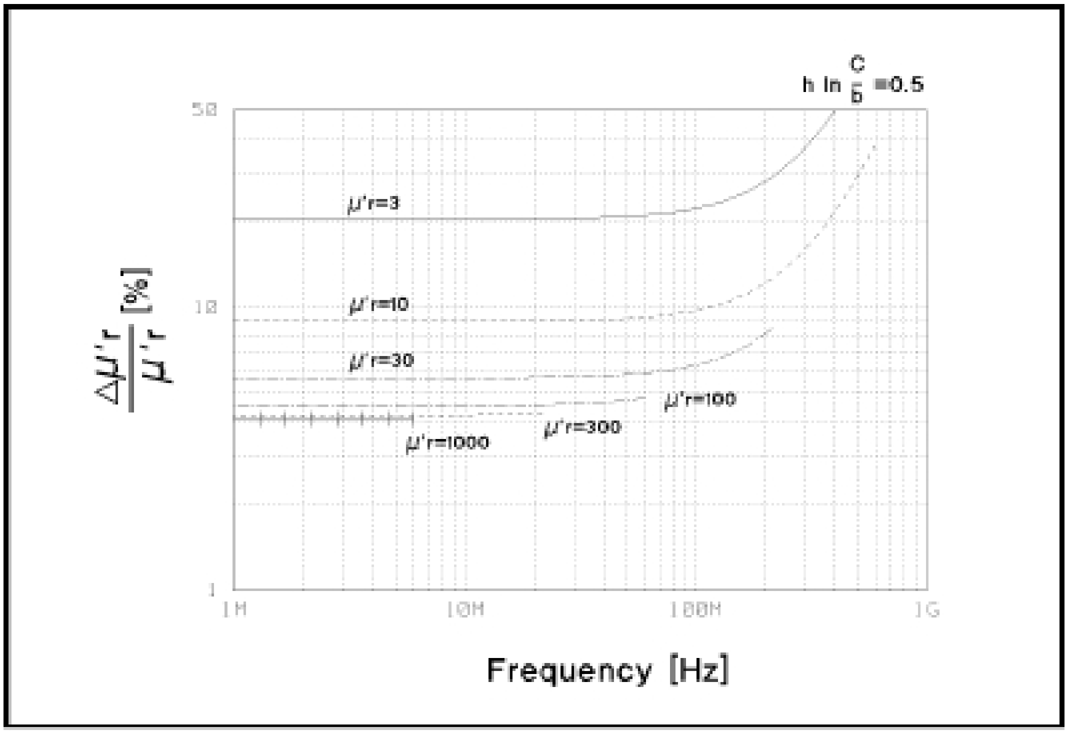


Figure 1-26. Typical Permeability Measurement Accuracy (@ F* = 0.5)

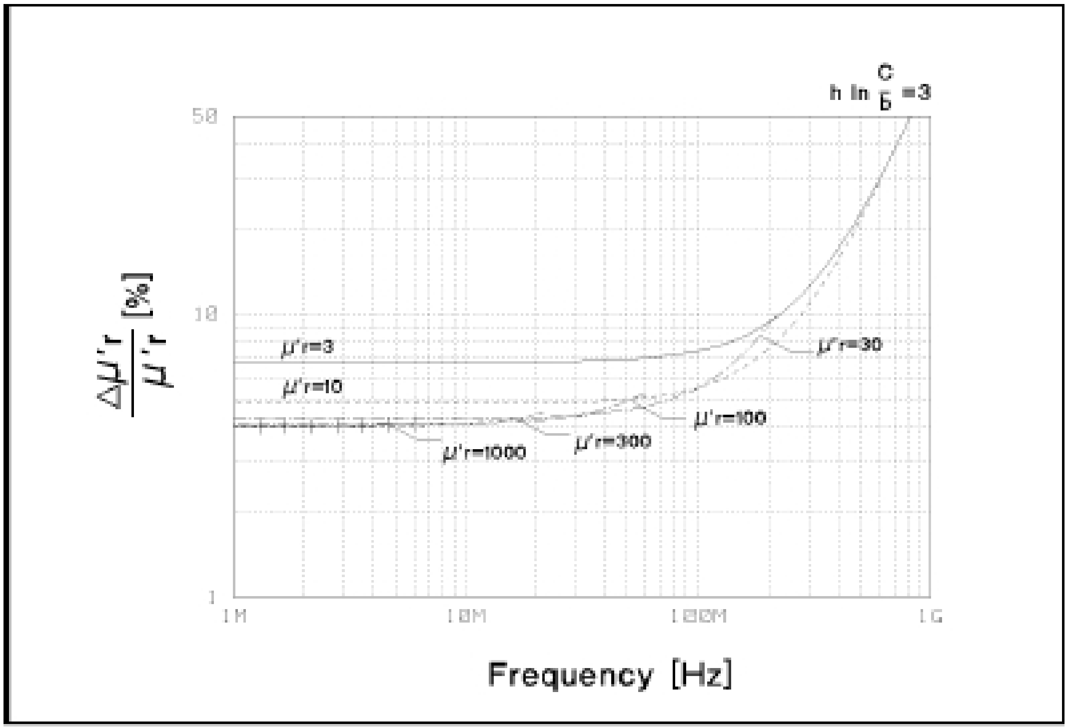


Figure 1-27. Typical Permeability Measurement Accuracy (@ F* = 3) $^{*}F = h\ln\frac{c}{b}$

Option 002 Material Measurement

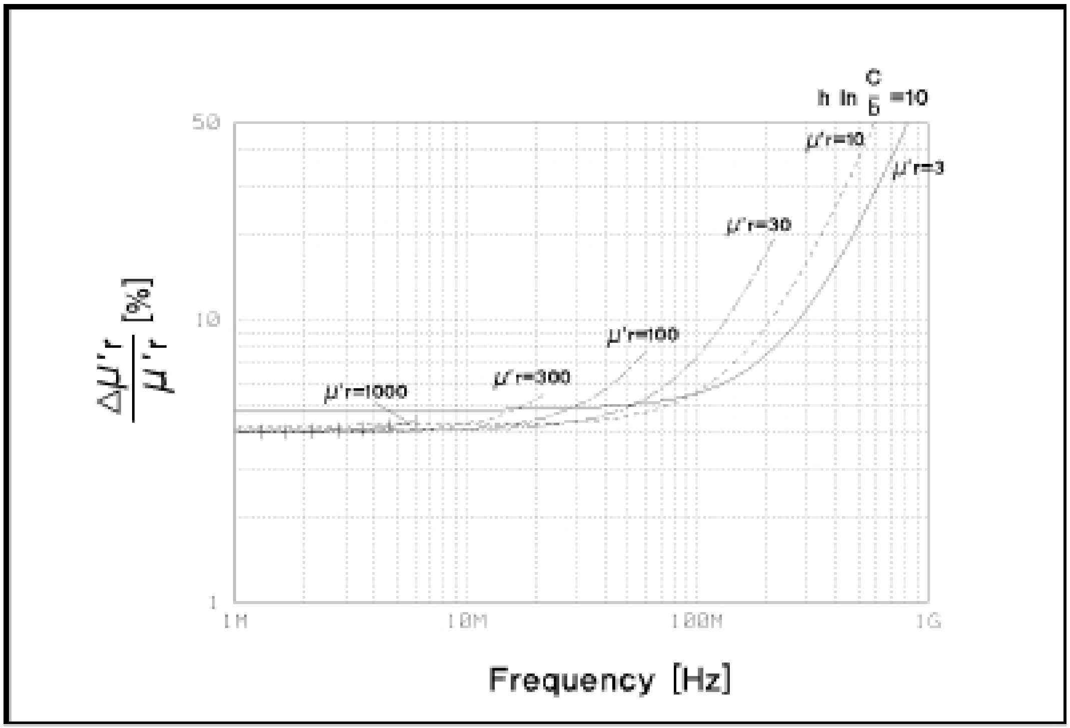


Figure 1-28. Typical Permeability Measurement Accuracy (@ F* = 10)

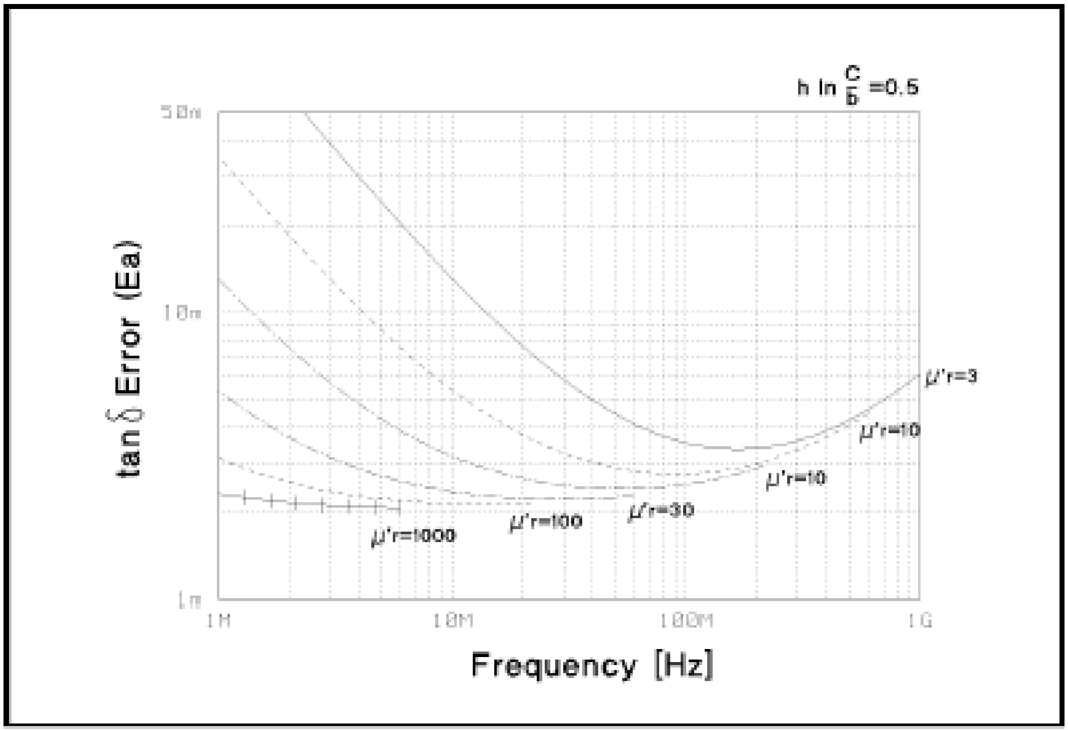


Figure 1-29. Typical Permeability Loss Tangent (tanδ) Measurement Accuracy (@ F* = 0.5)

$^{*}F = h\ln\frac{c}{b}$

Option 002 Material Measurement

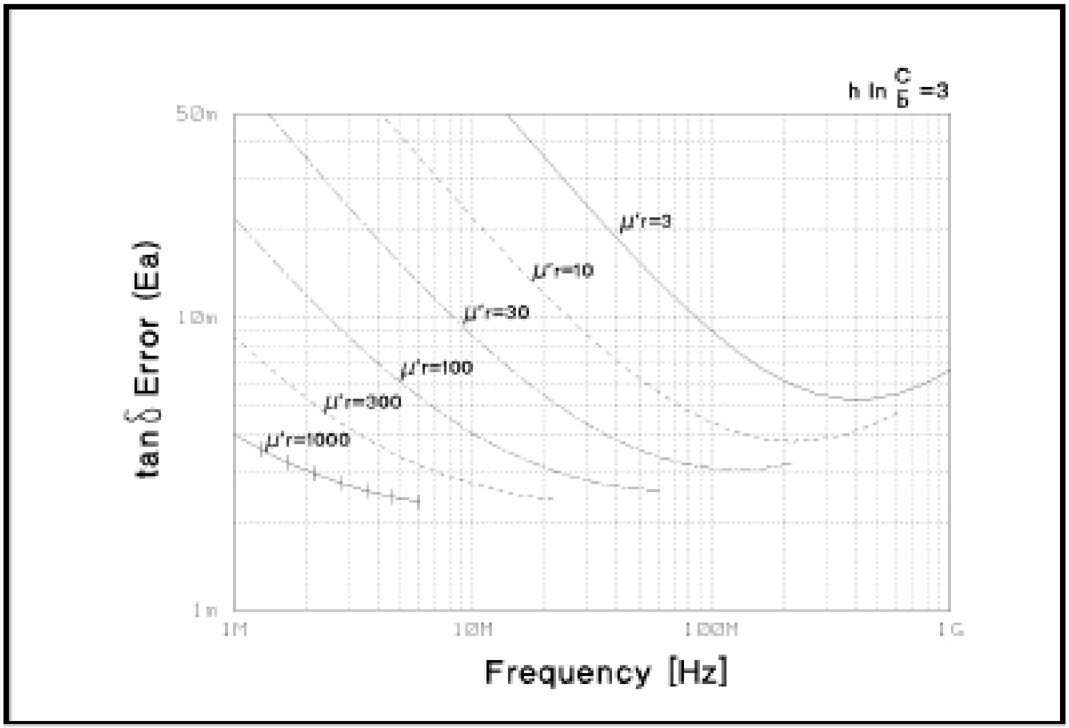


Figure 1-30. Typical Permeability Loss Tangent (tanδ) Measurement Accuracy (@ F* = 3)

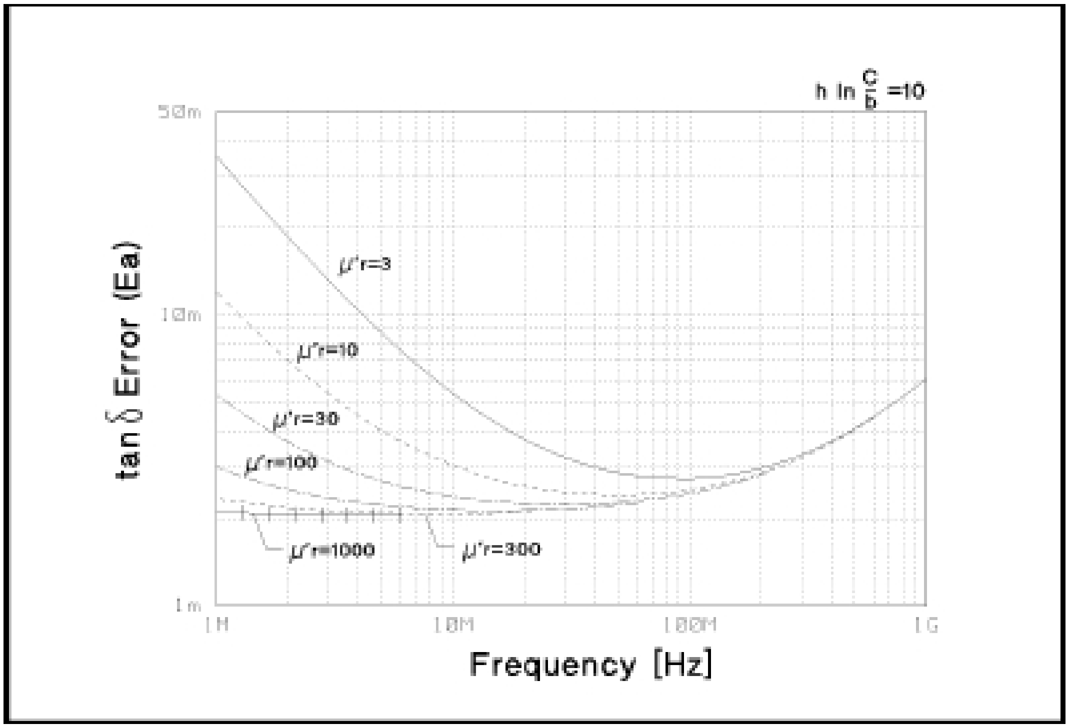


Figure 1-31. Typical Permeability Loss Tangent (tanδ) Measurement Accuracy (@ F* = 10)

$^*F = h\ln\frac{c}{b}$

Option 002 Material Measurement

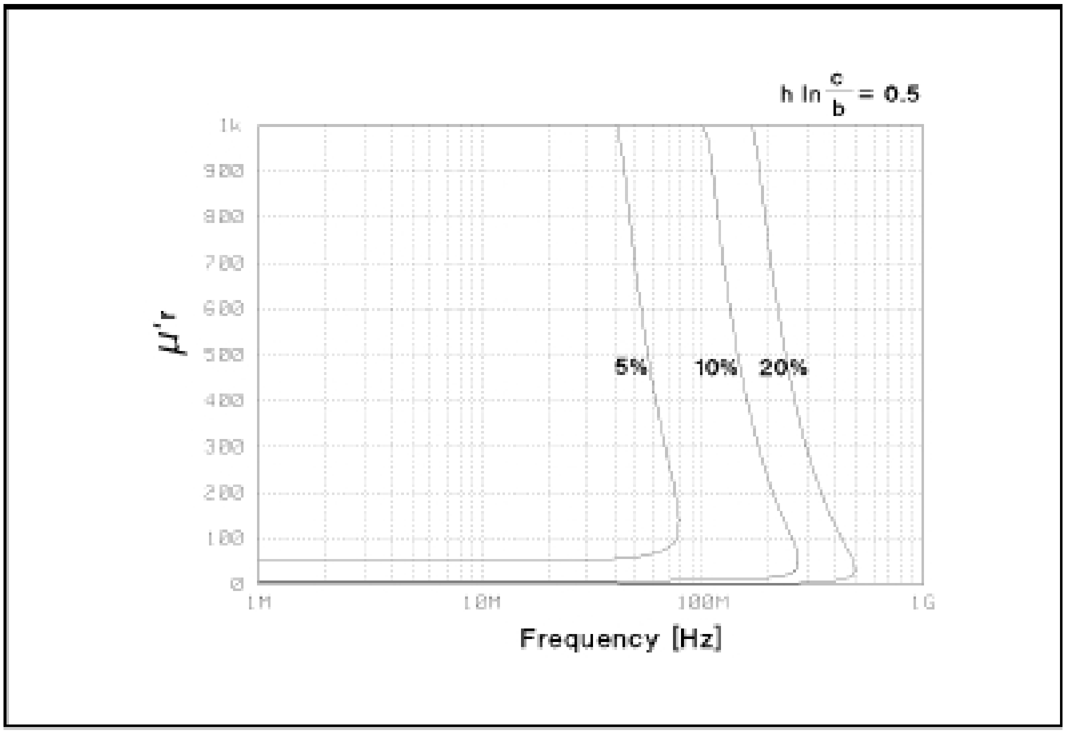


Figure 1-32. Typical Permeability Measurement Accuracy (μ_r vs. Frequency, @ F* = 0.5)

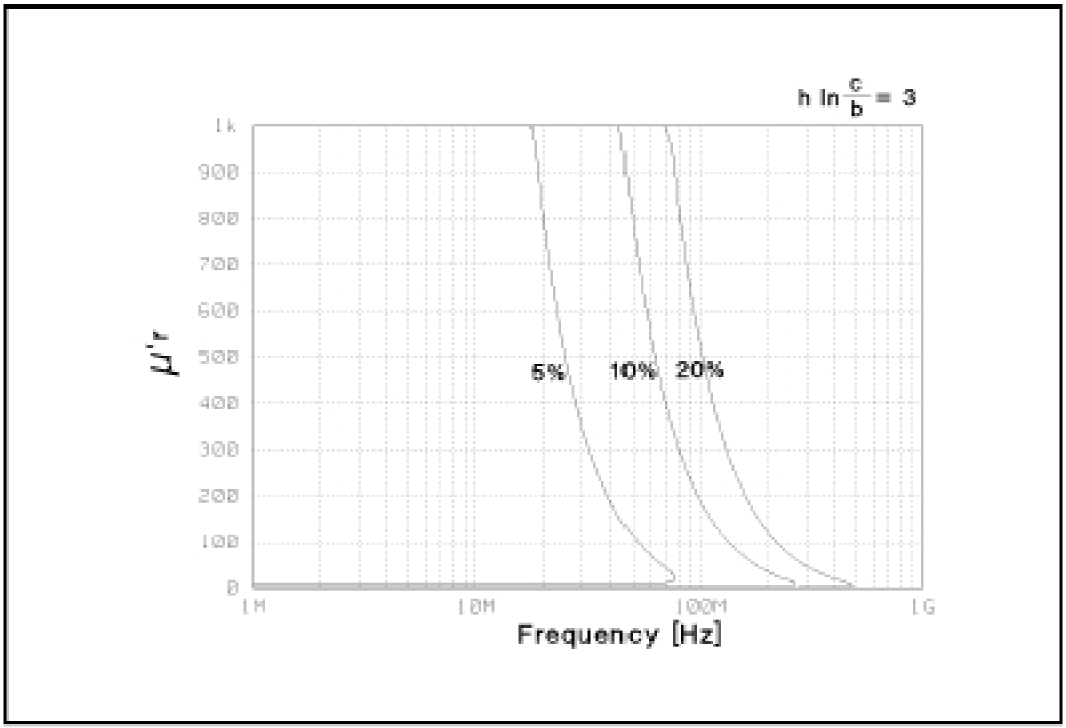


Figure 1-33. Typical Permeability Measurement Accuracy (μ_r vs. Frequency, @ F* = 3)

$^*F = h \ln \frac{c}{b}$

Option 002 Material Measurement

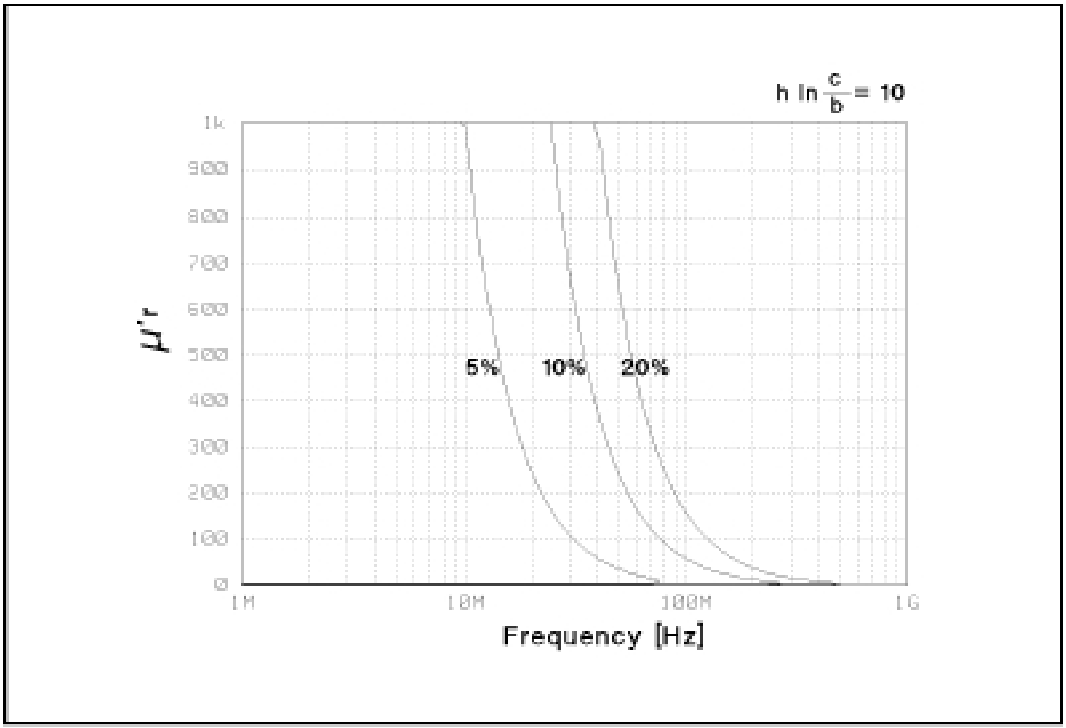


Figure 1-34. Typical Permeability Measurement Accuracy (μ_r vs. Frequency, @ F* = 10) $^{*}F = h\ln\frac{c}{b}$

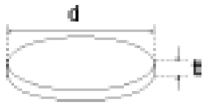
Option 002 Material Measurement

Applicable MUT (Material Under Test) Size . . . . See Tables 1-5 and 1-6
Maximum DC Bias Voltage / Current
Using the Agilent 16453A. . . . . ±40 V
Using the Agilent 16454A . . . . ±500 mA

Operating Temperature
Using the Agilent 16453A or 16454A . . . . –55°C to +200°C

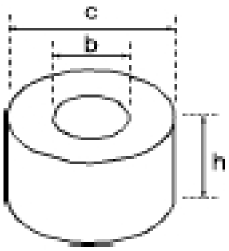
Operating Humidity
Wet bulb temperature < 40°C
Using the Agilent 16453A or 16454A . . . . up to 95% RH

Table 1-5. Applicable Dielectric Material Size Using with the Agilent 16453A



t	≤ 3 mm
d	≥ ϕ 15 mm

Table 1-6. Applicable Magnetic Material Size Using the Agilent 16454A



Fixture	**Small**		**Large**	
Holder	**A**	**B**	**C**	**D**
c	≤ ϕ 8 mm	≤ ϕ 6 mm	≤ ϕ 20 mm	≤ ϕ 20 mm
b	≥ ϕ 3.1 mm	≥ ϕ 3.1 mm	≥ ϕ 6 mm	≥ ϕ 5 mm
h	≤ 3 mm	≤ 3 mm	≤ 10 mm	≤ 10 mm

Material Measurement Accuracy with High Temperature Test Head

Option 002 Material Measurement Accuracy with Options 013 and 014 High Temperature Test Head (Typical)

Dielectric Material Measurement Accuracy with High Temperature Test Head (Typical)

Conditions of Dielectric Material Measurement Accuracy with High Temperature Test Head

- Environment temperature is within ±5°C of temperature at which calibration is done, and within 0°C to 40°C.
- High Temperature High Impedance Test Head must be used.
- Bending cable should be smooth and the bending angle less than 30°.
- Cable position should be kept in the same position after calibration measurement.
- OPEN/SHORT/50 Ω calibration must be done. Calibration ON.
- Measurement points are same as the calibration points.
- Averaging (on point) factor must be larger than 32 at which calibration is done.
- OSC level must be same as level at which calibration is done.
- OSC level is less than or equal to 0.25 V_{rms}, or greater than 0.25 V_{rms} and frequency range is within 1 MHz to 1 GHz.
- Environment temperature of the main frame is within ±5°C of temperature at which calibration is done, and within 0°C to 40°C.

ε_r' Accuracy ($\frac{\Delta\varepsilon'_{rm}}{\varepsilon'_{rm}}$). . . . . Same as accuracy at which a normal test head is used

Loss Tangent Accuracy of $\hat{\varepsilon}_r$ ($\Delta\tan\delta$) . . . . Same as accuracy at which a normal test head is used

At the following frequency points, instrument spurious characteristics could occasionally cause measurement errors to exceed specified value.

10.71 MHz	17.24 MHz	21.42 MHz	42.84 MHz
514.645 MHz	686.19333 MHz	1029.29 MHz	1327.38666 MHz

See “EMC” under “Others” in “General Characteristics.”
The excessive vibration and shock could occasionally cause measurement errors to exceed specified value.

Material Measurement Accuracy with High Temperature Test Head

Typical Effects of Temperature Drift on Dielectric Material Measurement Accuracy

When environment temperature is without ±5°C of temperature at which calibration is done, add the following measurement error.

ε_r' **Accuracy** $\left(\frac{\Delta\varepsilon'_{rm}}{\varepsilon'_{rm}}\right)$ . . . . $E_\varepsilon + E_{a3} + E_{b3}$ [%]

Loss Tangent Accuracy of $\overset{A}{\varepsilon}_r$ $(\Delta\tan\delta)$ . . . . $E_{\tan\delta\varepsilon}\ \frac{(E_{a3} + E_{b3})}{100}$

Where,

E_ε is ε_r' accuracy when a normal test head is used.
$E_{\tan\delta\varepsilon}$ is loss tangent accuracy when a normal test head is used.
E_{a3} is the effect of temperature drift on the accuracy as follows:

$$\mathbf{E_{a3}} = T_c\Delta T$$

E_{b3} is the hysterisis of the effect of temperature drift on the accuracy as follows:

$$\mathbf{E_{b3}} = \frac{T_c\Delta T}{3}$$

Where,

T_c is temperature coefficient as follows:

$$T_c = K_1 + K_2 + K_3$$

$$\mathbf{K_1} = 1 \times 10^{-6} \times (50 + 300f)$$

$$\mathbf{K_2} = 3 \times 10^{-6} \times (4 + 50f)\left(\frac{\varepsilon'_{rm}}{t}\ \frac{1}{|1 - (f/f_0)^2|} + 10\right)f$$

$$\mathbf{K_3} = 5 \times 10^{-3} \times (0.2 + 8f^2)\frac{1}{\left(\frac{\varepsilon'_{rm}}{t}\ \frac{1}{|1 - (f/f_0)^2|} + 10\right)f}$$

f : Measurement Frequency [GHz]

$f_0 = \frac{13}{\sqrt{\varepsilon'_{rm}}}$ [GHz]

t : Thickness of MUT [mm]

$\varepsilon'_{\mathbf{rm}}$: measured value of ε'_r

The illustrations of temperature coefficient T_c are shown in Figures 1-35 to 1-37.

ΔT is difference of temperature between measurement condition and calibration measurement condition as follows:

$$\Delta T = |T_{meas} - T_{cal}|$$

T_{meas} : Temperature of Test Head at measurement condition
T_{cal} : Temperature of Test Head at calibration measurement condition

Material Measurement Accuracy with High Temperature Test Head

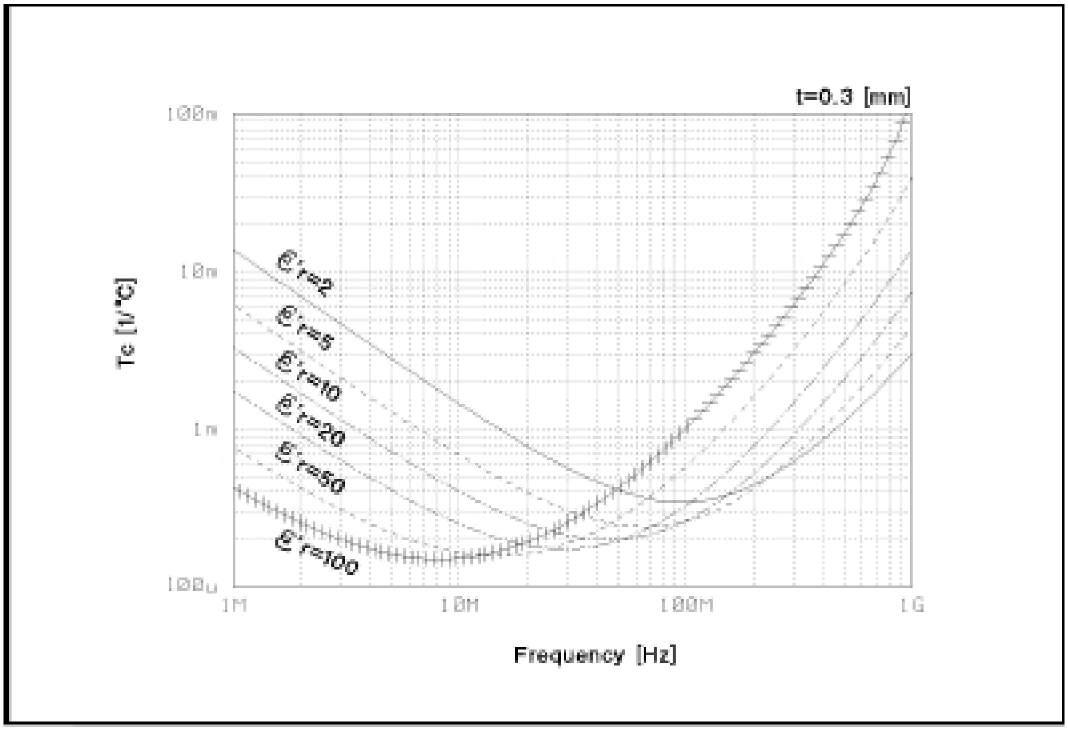


Figure 1-35. Typical Frequency Characteristics of Temperature Coefficient of ε_r' and Loss Tangent Accuracy (Thickness = 0.3 mm)

Material Measurement Accuracy with High Temperature Test Head

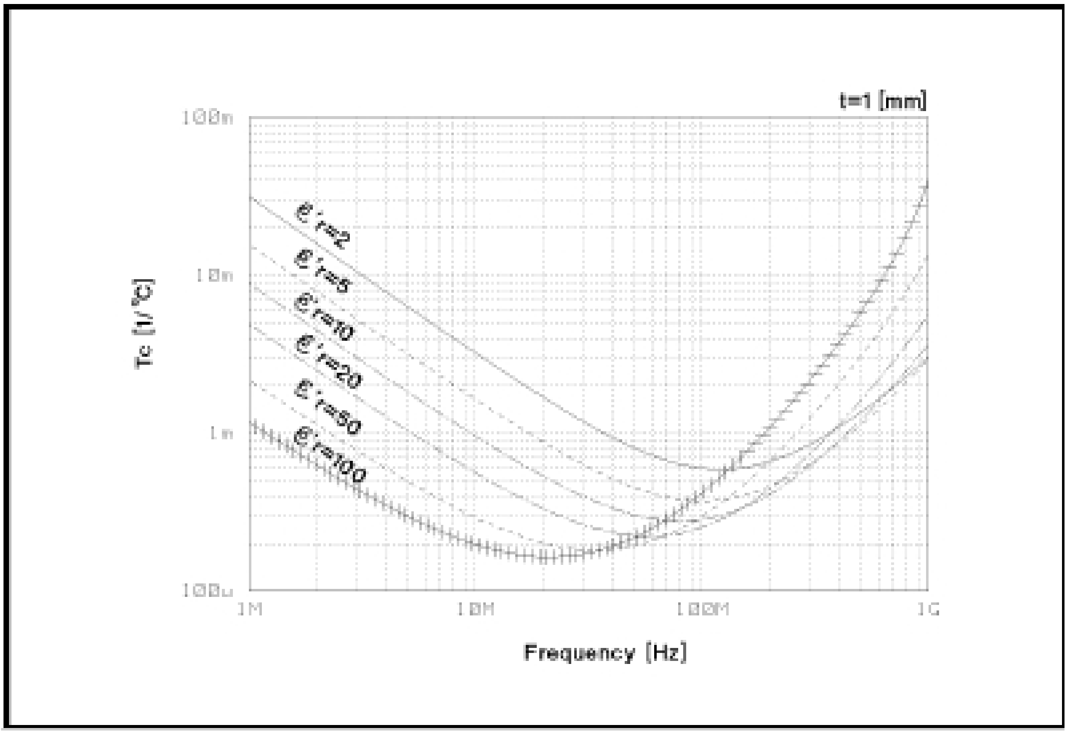


Figure 1-36. Typical Frequency Characteristics of Temperature Coefficient of ε_r' and Loss Tangent Accuracy (Thickness = 1 mm)

Material Measurement Accuracy with High Temperature Test Head

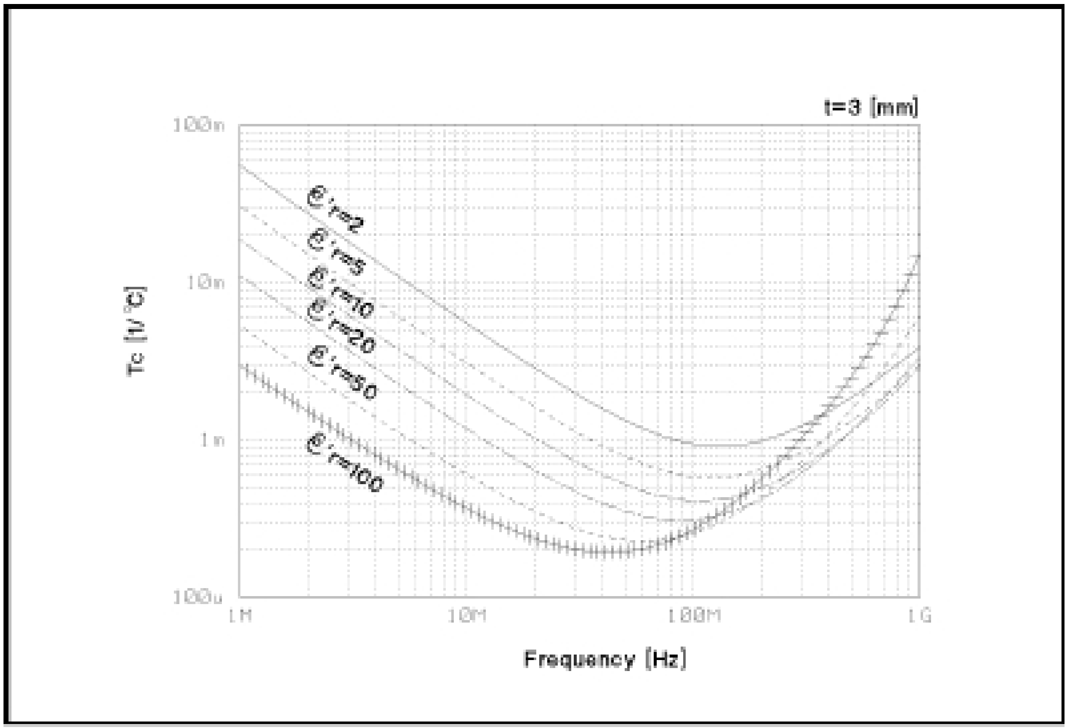


Figure 1-37. Typical Frequency Characteristics of Temperature Coefficient of ε_r' and Loss Tangent Accuracy (Thickness = 3 mm)

Material Measurement Accuracy with High Temperature Test Head

Material Measurement Accuracy with High Temperature Test Head (Typical)

Conditions of Dielectric Material Measurement Accuracy with High Temperature Test Head

- Environment temperature is within ±5°C of temperature at which calibration is done, and within 0°C to 40°C.
- High Temperature Low Impedance Test Head must be used.
- Bending cable should be smooth and the bending angle less than 30°.
- Cable position should be kept in the same position after calibration measurement.
- OPEN/SHORT/50 Ω calibration must be done. Calibration ON.
- Measurement points are same as the calibration points.
- Averaging (on point) factor must be larger than 32 at which calibration is done.
- OSC level must be same as level at which calibration is done.
- OSC level is less than or equal to 0.25 V_{rms}, or greater than 0.25 V_{rms} and frequency range is within 1 MHz to 1 GHz.
- Environment temperature of the main frame is within ±5°C of temperature at which calibration is done, and within 0°C to 40°C.

μ_r' Accuracy ($\frac{\Delta\mu'_{rm}}{\mu'_{rm}}$) . . . . Same as accuracy at which a normal test head is used

Loss Tangent Accuracy of μ_r'($\Delta\tan\delta$) . . . . Same as accuracy at which a normal test head is used

At the following frequency points, instrument spurious characteristics could occasionally cause measurement errors to exceed specified value.

10.71 MHz	17.24 MHz	21.42 MHz	42.84 MHz
514.645 MHz	686.19333 MHz	1029.29 MHz	1327.38666 MHz

See “EMC” under “Others” in “General Characteristics.”
The excessive vibration and shock could occasionally cause measurement errors to exceed specified value.

Material Measurement Accuracy with High Temperature Test Head

Typical Effects of Temperature Drift on Magnetic Material Measurement Accuracy

When environment temperature exceeds ±5°C of temperature at which calibration is done, add the following measurement error.

μ_r' Accuracy $\left(\frac{\Delta\mu'_{rm}}{\mu'_{rm}}\right)$ . . . . $E_\mu + E_{a3} + E_{b3}$

Loss Tangent Accuracy of $\hat{\mu}_r'$(Δtanδ) . . . . $E_{\tan\delta\mu} + \frac{(E_{a3} + E_{b3})}{100}$

Where,

E_μ is μ'_r accuracy when a normal test head is used.

$E_{\tan\delta\mu}$ is loss tangent accuracy when a normal test head is used.

E_{a3} is the effect of temperature drift on the accuracy as follows:

$$E_{a3} = T_c \Delta T$$

***E_{b3}** is the hysterisis of the effect of temperature drift on the accuracy as follows:

$$E_{b3} = \frac{T_c \Delta T}{3}$$

Where,

T_c is temperature coefficient as follows:

$$T_c = K_1 + K_2 + K_3$$

$$K_1 = 1 \times 10^{-6} \times (50 + 300f)$$

$$K_2 = 1 \times 10^{-2} \times (1 + 10f^2)\ \frac{|1 - 0.01\{F(\mu'_{rm} - 1) + 10\}f^2|}{\{F(\mu'_{rm} - 1) + 20\}f} + 10)f$$

$$K_3 = 2 \times 10^{-6} \times (1 + 30f)\ \frac{\{F(\mu'_{rm} - 1) + 20\}f}{|1 - 0.01\{F(\mu'_{rm} - 1) + 10\}f^2|}$$

f : Measurement Frequency [GHz]

$$F = h \ln \frac{c}{b}\ [\text{mm}]$$

h is the height of MUT [mm]
b is the inner diameter of MUT
c is the outer diameter of MUT
μ'_{rm} is the measured value of permeability

The illustrations of temperature coefficient T_c are shown in Figures 1-38 to 1-40.

ΔT is difference of temperature between measurement condition and calibration measurement condition as follows:

$$\Delta T = |T_{meas} - T_{cal}|$$

T_{meas} : Temperature of Test Head at measurement condition
T_{cal}: Temperature of Test Head at calibration measurement condition

Material Measurement Accuracy with High Temperature Test Head

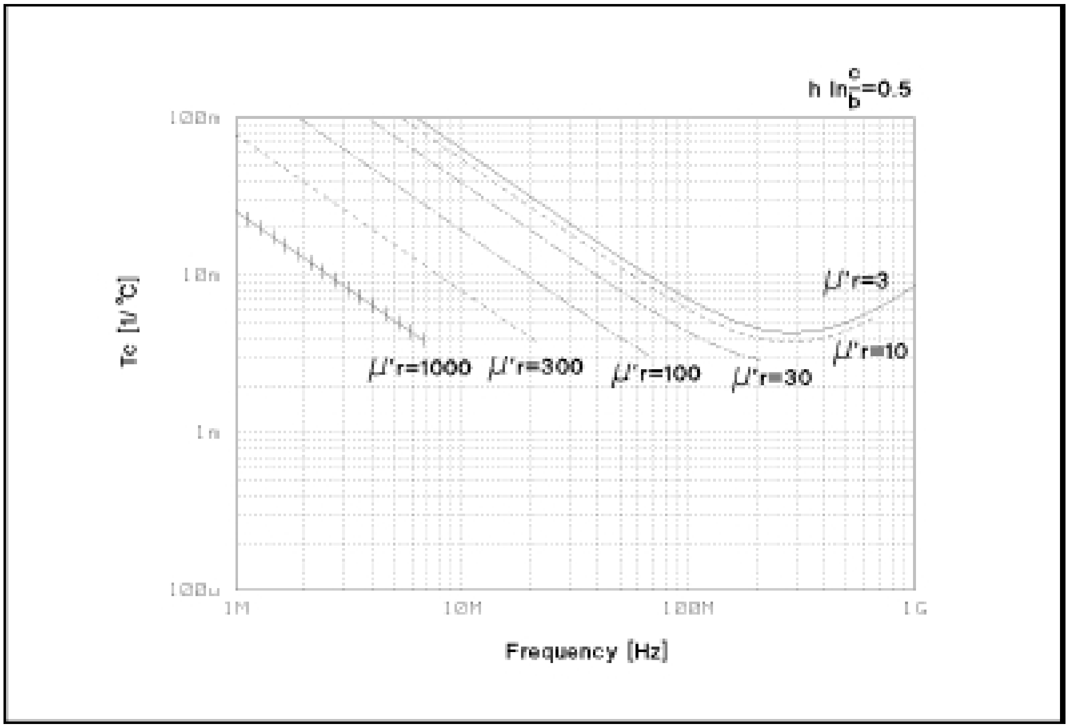


Figure 1-38. Typical Frequency Characteristics of Temperature Coefficient of μ_r' and Loss Tangent Accuracy (F* = 0.5)

$^*F = h\ln\frac{c}{b}$

Material Measurement Accuracy with High Temperature Test Head

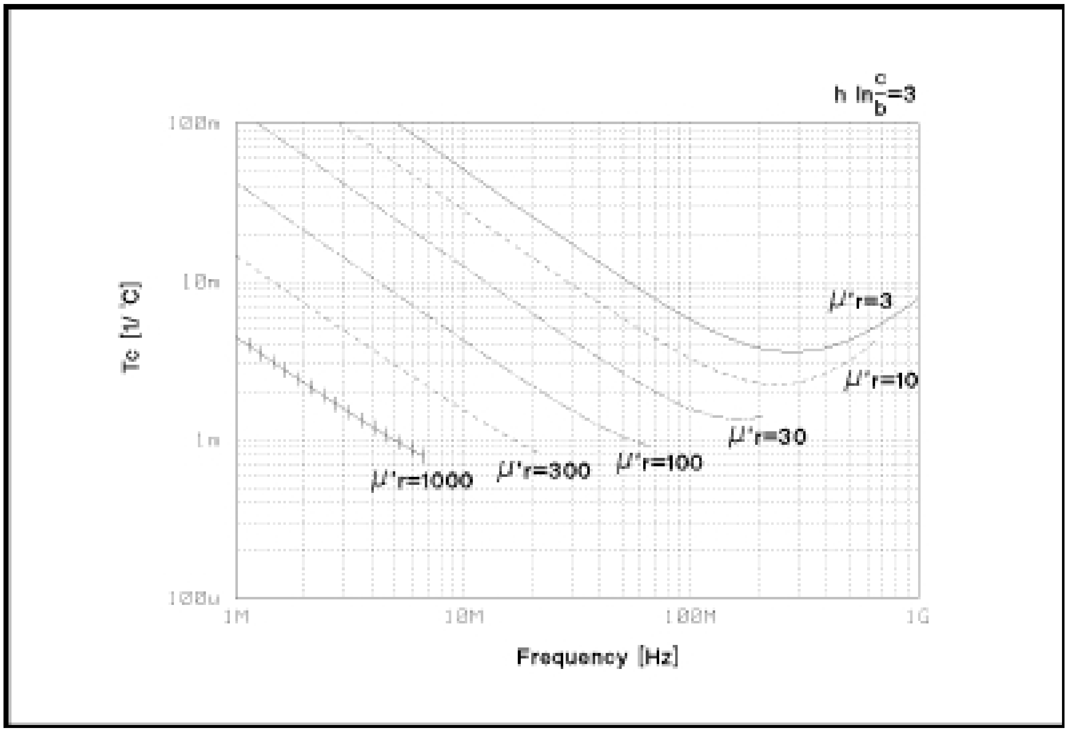


Figure 1-39. Typical Frequency Characteristics of Temperature Coefficient of μ_r' and Loss Tangent Accuracy (F* = 3)

$^{*}F = h\ln\frac{c}{b}$

Material Measurement Accuracy with High Temperature Test Head

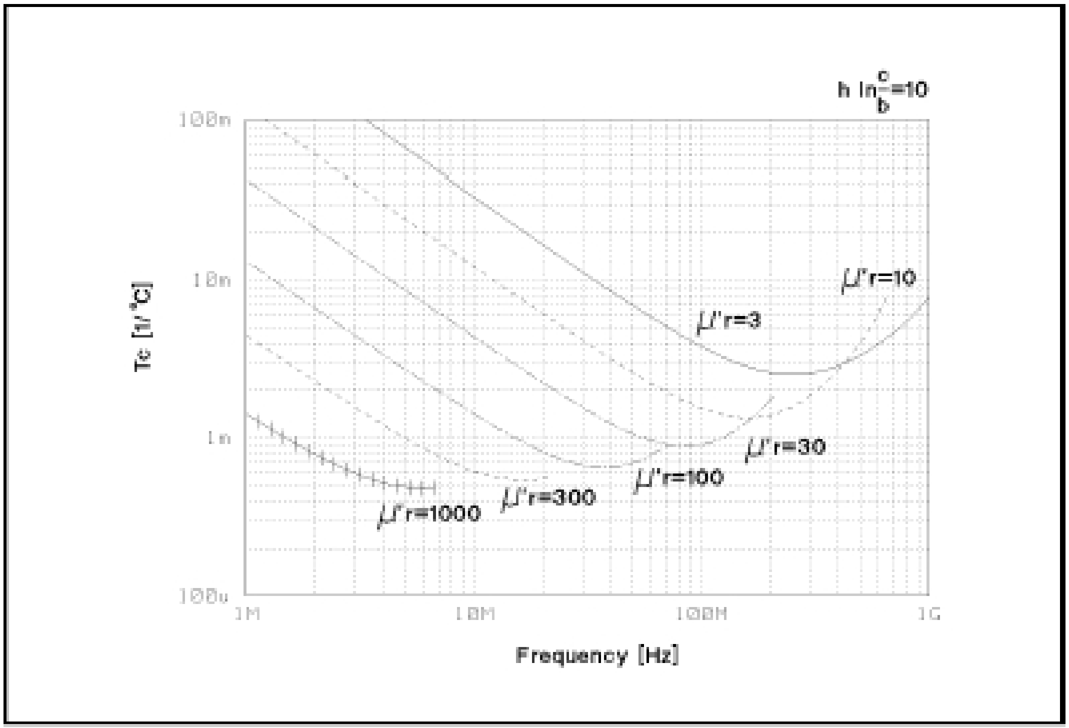


Figure 1-40. Typical Frequency Characteristics of Temperature Coefficient of μ_r' I and Loss Tangent Accuracy (F* = 10)

$^{*}F = h\ln\frac{c}{b}$

Furnished Accessories

Accessory	**Agilent part number**
Operating Manual	04291-90020
Programming Manual	04291-90027
Service Manual[1]	04291-90111
Program Disk Set	04291-18000
Power Cable[2]	
50 Ω Termination	04291-65006
0 Ω Termination	04191-85300
0 S Termination	04191-85302
Low-Loss Capacitor	04291-60042
Calibration Kit Carrying Case	04291-60041
APC-7 End Cap	16190-25011
Fixture Stand[3]	04291-60121
Pad	04291-09001
BNC Adapter[4]	1250-1859
Mini-DIN Keyboard	C3757-60401
Instrument BASIC User's Handbook	E2083-90000
Handle Kit[5]	5062-3991
Rack Mount Kit[6]	5062-3979
Rack Mount and Handle Kit[7]	5062-3985

1. Option OBW only
2. The power cable depends on where the instrument is used; see User's Guide.
3. Option 013 and 014 only
4. Option 1D5 only
5. Option 1CN only
6. Option 1CM only
7. Option 1CP only

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