Maury Microwave

User Guide

3.5mm Coaxial Calibration Kit

DC to 34 GHz

Model 8050CK30/31

8050-531 (A) 3/15

User Guide

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DC to 34 GHz

Model 8050CK30/31

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General Information

Calibration Kit Description

This series of **3.5mm** coaxial calibration kits is designed to provide accurate calibrations of network analyzers in the **DC to 34.0 GHz** range. Each of these kits includes all the necessary calibration standards and associated hardware needed for the accurate calibration of most network analyzers.

Refer to the ***Calibration Kits*** *Contents* section (see Appendix, Date Sheet Resources) for information on included components and available kit options.

NOTE: This document, calibration constants software, and data sheet can be downloaded from our website: ***maurymw.com***

NOTE: Legacy analyzer software is not on our website but is available for purchase.

Maintenance

This calibration kit is relatively maintenance free if the components are handled with the same care that is appropriate to all precision equipment. As with any precision component, proper care should be taken to assure clean mating surfaces, correct alignment when mating, and proper torquing of connectors or waveguide coupling screws. To help maintain the integrity of the components in this kit, routine visual inspection and cleaning of mating surfaces is recommended. Failure to do so may result in degraded repeatability and accuracy, as well as damage any mated devices.

Calibration

To maintain verification that a calibration kit is performing to traceable specifications, we recommend that all kits be periodically returned to Maury Microwave for calibration. The typical calibration cycle is one year, although actual need may vary depending on usage.

Supporting Test Port Adapters

When configuring a test setup, be sure that damaging stresses are not applied to the connectors on the test set. This is particularly critical when the attached components are heavy or long. Always properly support the test port adapters being used.

Electrostatic Discharge Precautions

Protection against electrostatic discharge (ESD) is essential while inspecting, cleaning, or making connections to connectors attached to a static-sensitive circuit, such as those found inside test sets.

When handling the connectors on the test set, be aware that you are coming in contact with exposed center conductors that are connected directly to the static-sensitive internal circuits of the network analyzer. Make sure that you and your equipment are well-grounded before inspecting, cleaning, or making connections to test set ports. Standard ESD precautions, such as the use of grounded wrist straps and grounded antistatic mats, are recommended.

Connector Description

Precision **3.5mm (APC3.5)** connectors are miniature, air-interface connectors for use up to 34 GHz. They feature extremely low VSWR and insertion loss, and are designed to non-destructively mate with standard SMA connectors. These connectors generally have a bead support and comply with the proposed USNC/IEC/SC46D – general precision connector instrument grade – GPC3.5B.

Connector Care

Precision connectors must be handled carefully if accurate calibrations and measurements are to be obtained. All connectors should be inspected prior to each use. For optimum measurement results, all interfaces should be visually inspected under magnification and cleaned on a regular basis. Proper connector contact pin depths should also be verified through regular inspections using a connector gage, such as the Maury Microwave **A050A series** connector gage kit, to insure that the connectors on both calibration devices and devices under test (DUTs) have contact pin depths within recommended tolerances. Refer to Maury data sheet ***5E-062*** (available on our website) for proper pin depth specifications.

- Care should be used whenever aligning connectors. Tighten connector coupling nuts using an appropriate torque wrench while holding the opposing connector with an open-end wrench.
- When disconnecting devices, take care not to rock or bend any of the connections. Disconnect devices by disengaging the coupling nuts and gently pulling the connectors apart in a straight line.
- Always use protective covers on all connectors when devices are not in use.
- Should a connector become damaged, it should be repaired before it is used any further or replaced immediately. A damaged connector can damage other mated connectors.

Connector Tightening

Damage to a calibration device or attaching connector can occur if the device is turned instead of the connector nut. ALWAYS turn the nut when making connections. Never turn the device itself.

Always use a torque wrench (Maury model **8799A1**) to final-tighten all connections. This will insure calibration accuracy and measurement repeatability.

When making connections, a **5/16 inch** open-end wrench or a **7/16 inch** open-end wrench may be required to hold the body of one device stationary while torquing the nut on the other device or cable. Both of these open-end wrenches are supplied with this calibration kit for this purpose.

Using the torque wrench:

- Hand-tighten the connection to be torqued by holding the calibration device steady and turning only the nut.
- Hold the torque wrench with your thumb and index finger, behind the groove in the handle (see **Figure 1**).
- Tighten the connection until the ball in the handle crests on the cam (as the handle begins to break). Do not "fully break" the handle of the torque wrench to reach the specified torque.
- Reverse the previous procedure to disconnect the connection.

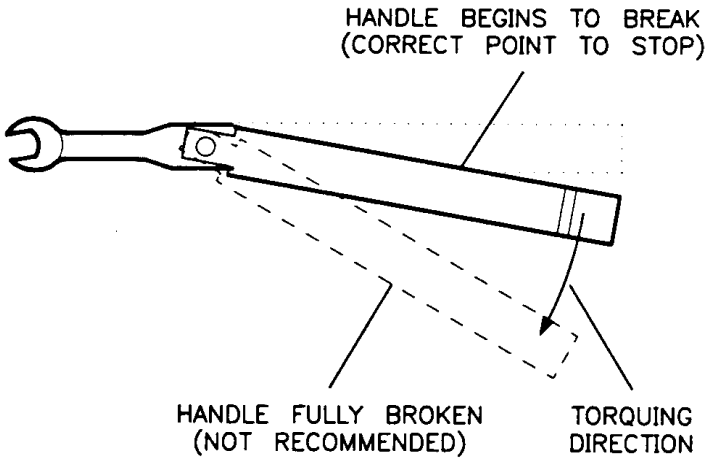

Figure 1. Using the Torque Wrench

TRL

- TRL is a general term used in this application to mean TRM/TRL/LRL.
- TRM means Thru, Reflect, Match.
- TRL means Thru, Reflect, Line.
- LRL means Line, Reflect, Line.

In practice, TRM is used for low frequencies where a very long air line would be required for the line standard. TRL is used for mid frequencies, and LRL is used for high frequencies where air line standards become too short to be practical. Your TRL-kit is equipped with four (4) air lines for making TRL/LRL calibrations.

Table 1 shows the calibration type required as a function of frequency. A network analyzer can be calibrated over the entire frequency range up to 34 GHz using a combination of these techniques. This calibration approach results in the best directivity and source match with these three calibration types and is recommended for the highest degree of accuracy.

Table 1. Calibration Type as a Function of Frequency

Frequency Range	Type of Calibration	Calibration Standards
DC — 800 MHz	TRM	Fixed Termination
160 MHz — 800 MHz	TRL	15cm Air Line
800 MHz — 2.5 GHz	TRL	5cm Air Line
2.5 GHz — 12.5 GHz	LRL	5cm & 6cm Air Lines
12.5 GHz — 34.0 GHz	LRL	5cm & 5.3cm Air Lines

NOTE: *The TRL-kit air line lengths are designed to meet NIST and Keysight recommendations of 30 degrees phase margin.*

TRM/TRL/LRL Calibration

To calibrate a network analyzer over the entire frequency range with the highest degree of accuracy, perform the following steps (see **Table 1** and **Figure 2**):

a. Perform a TRM (through-reflect-match) calibration from the lowest frequency of your network analyzer to 160 MHz using the fixed termination, thru connection and short circuit termination.

b. Perform a TRL (through-reflect-line) calibration from 160 MHz to 800 MHz using the through connection and 15cm air line.

c. Perform a TRL (through-reflect-line) calibration from 800 MHz to 2.5 GHz using the through connection and 5cm air line.

d. Perform an LRL calibration from 2.5 GHz to 12.5 GHz using the 5cm air lines (as the thru reference) and the 6cm air line. Use caution to select the correct air line. They are not interchangeable.

e. Perform an LRL calibration from 12.5 GHz to 34.0 GHz using the 5cm air line (as the through reference) and the 5.3cm air line. Use caution to select the correct air line. They are not interchangeable (see the following notes).

NOTE: All the air lines are labeled. Use extreme caution not to mix up the center conductors to avoid damage. For detailed TRL calibration instructions, you should refer to your network analyzer operating manual.

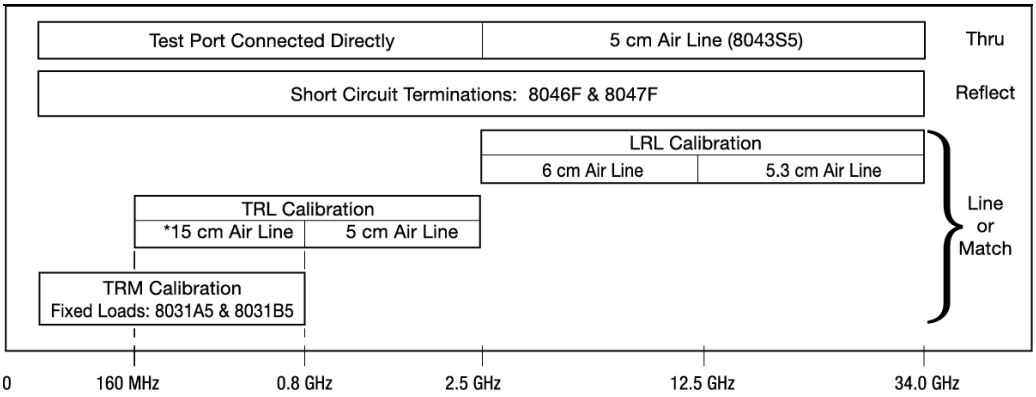

Figure 2. TRM/TRL/LRL Calibration

Other Examples of TRL Calibrations

Narrower bandwidths will only require the standards in **Figure 2** even though the analyzer will always list all of the possible standards. For example, to calibrate from 800 MHz to 2.5 GHz, only a through connection (test ports connected together), short, and the 5cm line are needed for calibration. The following examples illustrate the type of calibration and the air lines required as a function of frequency:

1. To calibrate from 160 MHz - 0.8 GHz, perform a TRL calibration using the 15cm air line.

2. To calibrate from 0.8 GHz - 2.5 GHz, perform a TRL calibration using the 5cm air line.

3. To calibrate from 2 - 18 GHz requires multiple calibrations as follows:

    a. Perform a TRL calibration from 2 - 2.5 GHz using the 5cm air line.

    b. Perform an LRL calibration from 2.5 - 12.5 GHz using the 5cm air line (as the thru reference) and the 6cm air line.

    c. Perform an LRL calibration from 12.5 - 18 GHz using the 5cm air line (as the thru reference) and the 5.3cm air line.

NOTE: Use caution to avoid getting the air lines mixed up. Use extreme care to not interchange the center conductors (this will result in damage).

Verifying Calibration Accuracy by Measuring Source Match

An easy way to check that your calibration went well is to measure source match. During each of the calibration methods, a short circuit was connected to the test port(s). Following calibration, if the short circuit is reconnected to the test port and the analyzer is set to measure S11 (displayed in dB), we'd expect to see a straight line with very little loss. If we inserted an air line between the short and the test port, we'd expect to see a straight line with more loss, with the loss increasing with frequency. What you will actually see is some ripple caused by the residual reflections of the test port interacting with the reflections from the short. This ripple shows the combined effects of both source match and directivity. For TRL/LRL calibrations, source match and directivity are about the same level. For OSL calibrations, directivity is typically 6 to 10 dB better than the source match. The amount of ripple usually ranges from 0.02 dB peak-to-peak (a very good calibration) to 1 dB peak-to-peak (not a very good calibration). TRL/LRL calibrations will yield the best results and fixed load calibrations will yield the worst.

Source match can be measured as follows:

a. Connect the 15cm air line to the measurement port, terminated with the appropriate short circuit.

b. Measure the return loss and adjust the scale resolution to detect the ripple pattern on the Return Loss display (typically 0.1 - 0.2 dB, peak-to-peak).

c. Measure the peak-to-peak amplitude of the ripple pattern. To adjust for slope, measure two peaks on each side of a valley and average.

d. Use **Table 7** to convert peak-to-peak ripple to source match.

Calibration Kit Contents

Standard Components – 8050CK30

1 ea	Short, female	8046F
1 ea	Short, male	8047F
1 ea	Fixed Termination, female	8031A5
1 ea	Fixed Termination, male	8031B5
1 ea	Female to male air line (5cm)	8043S5
1 ea	Female to male air line (5.30cm)	8043S5.3
1 ea	Female to male air line (6cm)	8043S6
1 ea	Female to male air line (15cm)	8043S15
1 ea	5/16 Torque Wrench, 8in.lbs	8799A1
1 ea	Wrench, 5/16	8770Z6
1 ea	Wrench, 7/16	8770Z7
1 ea	Case Assembly	

Standard Components – 8050CK31

1 ea	Short, female	8046F
1 ea	Short, male	8047F
1 ea	Fixed Termination, female	8031A5
1 ea	Fixed Termination, male	8031B5
1 ea	Adapter, male to male	8021B2
1 ea	Adapter, female to male	8021C2
1 ea	Adapter, female to female	8021A2
1 ea	Female to male air line (5cm)	8043S5
1 ea	Female to male air line (5.30cm)	8043S5.3
1 ea	Female to male air line (6cm)	8043S6
1 ea	Female to male air line (15cm)	8043S15
1 ea	5/16 Torque Wrench, 8in.lbs	8799A1
1 ea	Wrench, 5/16	8770Z6
1 ea	Wrench, 7/16	8770Z7
1 ea	Case Assembly	

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Standard Definitions

Anritsu Network Analyzers

Table 2. Male Standard Definitions for Anritsu

Male Open Device	
C0	62.54 e-15
C1	-1284.00 e-27
C2	107.60 e-36
C3	-1.89 e-45
Offset Length	0.434 cm
Serial Number	00000

Male Short Device	
Offset Length	0.500 cm
Serial Number	00000

Table 3. Female Standard Definitions for Anritsu

Female Open Device	
C0	63.17 e-15
C1	-1178.00 e-27
C2	109.60 e-36
C3	-2.15 e-45
Offset Length	0.434 cm
Serial Number	00000

Female Short Device	
Offset Length	0.500 cm
Serial Number	00000

For specific loading instructions, see ***Anritsu loading instructions,*** which can be downloaded from our website: ***maurymw.com***.

Table 4. Anritsu TRL Air Line Lengths

Air Line/Short Model No.	Length (cm)
8043S5	4.99364
8043S5.3	5.2959
8043S6	5.99694
8043S15	14.98346

For specific loading instructions, see ***Anritsu loading instructions,*** which can be downloaded from our website: ***maurymw.com***.

Table 5. Standard Definitions for Keysight

Standard [1]			C0 x10^{-15} F	C1 x10^{-27} F/Hz	C2 x10^{-36} F/Hz^2	C3 x10^{-45} F/Hz^3	Fixed or Sliding [2]	Offset			Frequency GHz		Coax or W/G	Standard Label
	Type	Description	L0 x10^{-12} H	L1 x10^{-24} H/Hz	L2 x10^{-33} H/Hz^2	L3 x10^{-42} H/Hz^3		Delay ps	Z_0 [3] Ω	Loss [4] GΩ/s	Min	Max		
	Short	8046F Female Short	0.0	0.0	0.0	0.0		16.684	50	1.3	0	999	Coax	8046F
	Short	8047F Male Short	0.0	0.0	0.0	0.0		16.684	50	1.3	0	999	Coax	8047F
	Load	8031A( ) Broadband Female Load					Fixed	0	50	0	0	999	Coax	8031A( ) BB
	Load	8031B( ) Broadband Male Load					Fixed	0	50	0	0	999	Coax	8031B( ) BB
	Thru	Thru (0 cm)						0	50	1.3	0	999	Coax	Thru[5]
	Thru	THRU - TRL (0 cm)						0.0	50	1.3	0.0	2.500001	Coax	THRU - TRL[5]
	Thru	8043S5 LINE (5 cm)						166.62	50	1.3	0.800	2.500001	Coax	8043S5
	Thru	8043S15 LINE (15 cm)						499.96	50	1.3	0.160	0.800001	Coax	8043S15
	Thru	8043S5.3 LINE (5.3 cm)						176.72	50	1.3	12.500	34.000001	Coax	8043S5.3
	Thru	8043S6 LINE (6 cm)						200.10	50	1.3	2.500	12.500001	Coax	8043S6
	Thru	8043S5 THRU (5 cm)						166.62	50	1.3	2.500	34.000001	Coax	8043S5 THRU
	Load	8031A( ) TRM Female Load					Fixed	0.0	50	0.0	0.0	800.001	Coax	8031A( ) TRM
	Load	8031B( ) TRM Male Load					Fixed	0.0	50	0.0	0.0	800.001	Coax	8031B( ) TRM

[1] Open, short, load, delay/thru, or arbitrary impedance.
[2] Load or arbitrary impedance only.
[3] Z_0 normalized.
[4] Skin loss factor, normalized at 1 GHz.
[5] Test ports connected directly.

For specific loading instructions, see ***Keysight loading instructions***, which can be downloaded from our website: ***maurymw.com***

Rohde & Schwarz Network Analyzers

Table 6. Standard Definitions for Rohde & Schwarz

Through (MF) Label = THRU TRL 0 cm Min Freq = 0 Hz Max Freq = 34.0 GHz Length = 0 mm Loss = 0 dB/√GHz	Reflect (M) Label = 8047F Min Freq = 0 Hz Max Freq = 34.0 GHz Length = 5.002 mm Loss = 0.0038 dB/√GHz
Line (MF) Label = LINE 15 cm Min Freq = 0.160 GHz Max Freq = 0.801 GHz Length = 149.884 mm Loss = 0.0565 dB/√GHz	Reflect (F) Label = 8046F Min Freq = 0 Hz Max Freq = 34.0 GHz Length = 5.002 mm Loss = 0.0038 dB/√GHz
Line (MF) Label = LINE 5 cm Min Freq = 0.800 GHz Max Freq = 2.51 GHz Length = 49.951 mm Loss = 0.0188 dB/√GHz	Line (MF) Label = LINE 6 cm Min Freq = 2.5 GHz Max Freq = 12.51 GHz Length = 59.988 mm Loss = 0.0226 dB/√GHz
Line (MF) Label = LINE 5.3 cm Min Freq = 12.50 GHz Max Freq = 34 GHz Length = 52.979 mm Loss = 0.0200 dB/√GHz	

For specific loading instructions, see ***Rohde & Schwarz loading instructions***, which can be downloaded from our website: ***maurymw.com***.

Table 7. Peak-to-Peak Ripple (dB) vs. Source Match vs. VSWR

P–P	SM	VSWR	P–P	SM	VSWR	P–P	SM	VSWR	P–P	SM	VSWR	P–P	SM	VSWR
0.001	84.8	1.000	0.051	50.7	1.006	0.102	44.7	1.012	0.205	38.6	1.024	0.455	31.8	1.053
0.002	78.8	1.000	0.052	50.5	1.006	0.104	44.5	1.012	0.210	38.4	1.024	0.460	31.7	1.054
0.003	75.3	1.000	0.053	50.3	1.006	0.106	44.3	1.012	0.215	38.2	1.025	0.465	31.6	1.054
0.004	72.8	1.000	0.054	50.2	1.006	0.108	44.2	1.012	0.220	38.0	1.025	0.470	31.5	1.055
0.005	70.8	1.001	0.055	50.0	1.006	0.110	44.0	1.013	0.225	37.8	1.026	0.475	31.4	1.055
0.006	69.2	1.001	0.056	49.8	1.006	0.112	43.8	1.013	0.230	37.6	1.027	0.480	31.3	1.056
0.007	67.9	1.001	0.057	49.7	1.007	0.114	43.7	1.013	0.235	37.4	1.027	0.485	31.2	1.057
0.008	66.7	1.001	0.058	49.5	1.007	0.116	43.5	1.013	0.240	37.3	1.028	0.490	31.1	1.057
0.009	65.7	1.001	0.059	49.4	1.007	0.118	43.4	1.014	0.245	37.1	1.028	0.495	31.0	1.058
0.010	64.8	1.001	0.060	49.2	1.007	0.120	43.2	1.014	0.250	36.9	1.029	0.500	30.9	1.058
0.011	64.0	1.001	0.061	49.1	1.007	0.122	43.1	1.014	0.255	36.7	1.030	0.505	30.9	1.059
0.012	63.2	1.001	0.062	49.0	1.007	0.124	43.0	1.014	0.260	36.6	1.030	0.510	30.8	1.060
0.013	62.5	1.001	0.063	48.8	1.007	0.126	42.8	1.015	0.265	36.4	1.031	0.515	30.7	1.060
0.014	61.9	1.002	0.064	48.7	1.007	0.128	42.7	1.015	0.270	36.2	1.031	0.520	30.6	1.061
0.015	61.3	1.002	0.065	48.6	1.007	0.130	42.6	1.015	0.275	36.1	1.032	0.525	30.5	1.061
0.016	60.7	1.002	0.066	48.4	1.008	0.132	42.4	1.015	0.280	35.9	1.032	0.530	30.4	1.062
0.017	60.2	1.002	0.067	48.3	1.008	0.134	42.3	1.015	0.285	35.8	1.033	0.535	30.4	1.063
0.018	59.7	1.002	0.068	48.2	1.008	0.136	42.2	1.016	0.290	35.6	1.034	0.540	30.3	1.063
0.019	59.2	1.002	0.069	48.0	1.008	0.138	42.0	1.016	0.295	35.5	1.034	0.545	30.2	1.064
0.020	58.8	1.002	0.070	47.9	1.008	0.140	41.9	1.016	0.300	35.3	1.035	0.550	30.1	1.064
0.021	58.4	1.002	0.071	47.8	1.008	0.142	41.8	1.016	0.305	35.2	1.035	0.555	30.0	1.065
0.022	58.0	1.003	0.720	47.7	1.008	0.144	41.7	1.017	0.310	35.0	1.036	0.560	30.0	1.066
0.023	57.6	1.003	0.073	47.5	1.008	0.146	41.5	1.017	0.315	34.9	1.037	0.565	29.9	1.066
0.024	57.2	1.003	0.074	47.4	1.009	0.148	41.4	1.017	0.320	34.8	1.037	0.570	29.8	1.067
0.025	56.8	1.003	0.075	47.3	1.009	0.150	41.3	1.017	0.325	34.6	1.038	0.575	29.7	1.067
0.026	56.5	1.003	0.076	47.2	1.009	0.152	41.2	1.018	0.330	34.5	1.038	0.580	29.7	1.068
0.027	56.2	1.003	0.077	47.1	1.009	0.154	41.1	1.018	0.335	34.4	1.039	0.585	29.6	1.068
0.028	55.9	1.003	0.078	47.0	1.009	0.156	41.0	1.018	0.340	34.3	1.040	0.590	29.5	1.069
0.029	55.6	1.003	0.079	46.9	1.009	0.158	40.9	1.018	0.345	34.1	1.040	0.595	29.5	1.070
0.030	55.3	1.003	0.080	46.8	1.009	0.160	40.8	1.019	0.350	34.0	1.041	0.600	29.4	1.070
0.031	55.0	1.004	0.081	46.6	1.009	0.162	40.6	1.019	0.355	33.9	1.041	0.605	29.3	1.071
0.032	54.7	1.004	0.082	46.5	1.009	0.164	40.5	1.019	0.360	33.8	1.042	0.610	29.2	1.071
0.033	54.4	1.004	0.083	46.4	1.010	0.166	40.4	1.019	0.365	33.6	1.042	0.615	29.2	1.072
0.034	54.2	1.004	0.084	46.3	1.010	0.168	40.3	1.019	0.370	33.5	1.043	0.620	29.1	1.073
0.035	53.9	1.004	0.085	46.2	1.010	0.170	40.2	1.020	0.375	33.4	1.044	0.625	29.0	1.073
0.036	53.7	1.004	0.086	46.1	1.010	0.172	40.1	1.020	0.380	33.3	1.044	0.630	29.0	1.074
0.037	53.4	1.004	0.087	46.0	1.010	0.174	40.0	1.020	0.385	33.2	1.045	0.635	28.9	1.074
0.038	53.2	1.004	0.088	45.9	1.010	0.176	39.9	1.020	0.390	33.1	1.045	0.640	28.8	1.075
0.039	53.0	1.004	0.089	45.8	1.010	0.178	39.8	1.021	0.395	33.0	1.046	0.645	28.8	1.076
0.040	52.8	1.005	0.090	45.7	1.010	0.180	39.7	1.021	0.400	32.9	1.047	0.650	28.7	1.076
0.041	52.6	1.005	0.091	45.6	1.011	0.182	39.6	1.021	0.405	32.7	1.047	0.655	28.6	1.077
0.042	52.3	1.005	0.092	45.5	1.011	0.184	39.5	1.021	0.410	32.6	1.048	0.660	28.6	1.077
0.043	52.1	1.005	0.093	45.5	1.011	0.186	39.5	1.022	0.415	32.5	1.048	0.665	28.5	1.078
0.044	51.9	1.005	0.094	45.4	1.011	0.188	39.4	1.022	0.420	32.4	1.049	0.670	28.4	1.079
0.045	51.7	1.005	0.095	45.3	1.011	0.190	39.3	1.022	0.425	32.3	1.050	0.675	28.4	1.079
0.046	51.6	1.005	0.096	45.2	1.011	0.192	39.2	1.022	0.430	32.2	1.050	0.680	28.3	1.080
0.047	51.4	1.005	0.097	45.1	1.011	0.194	39.1	1.022	0.435	32.1	1.051	0.685	28.3	1.080
0.048	51.2	1.006	0.098	45.0	1.011	0.196	39.0	1.023	0.440	32.0	1.051	0.690	28.2	1.081
0.049	51.0	1.006	0.099	44.9	1.011	0.198	38.9	1.023	0.445	31.9	1.052	0.695	28.1	1.082
0.050	50.8	1.006	0.100	44.8	1.012	0.200	38.8	1.023	0.450	31.8	1.052	0.700	28.1	1.082

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Appendix

Data Sheet Resources

2Z-059 – TRL/LRL VNA Calibration Kits (3.5mm)
http://maurymw.com/pdf/datasheets/2Z-059.pdf

2Y-001 – Connector Gages and Connector Gage Kits
http://maurymw.com/pdf/datasheets/2Y-001.pdf

2Y-049 – Metrology Grade 2.92/3.5mm Digital Connector Gage Kit
http://maurymw.com/pdf/datasheets/2Y-049.pdf

2Y-050A – Torque Wrenches
http://maurymw.com/pdf/datasheets/2Y-050A.pdf

5E-062 – Precision 3.5mm Coaxial Connectors
http://maurymw.com/pdf/datasheets/5E-062.pdf

2Z-001 – Test Port Cables and Adapters (2.4mm, 2.92mm, 3.5mm, & 7mm)
http://maurymw.com/pdf/datasheets/2Z-001.pdf

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Web Resources

Maury Calibration Kits
http://maurymw.com/Precision/VNA_Cal_Kits.php

Maury Precision Coaxial and Waveguide-to-Coaxial Adapters
http://maurymw.com/Finder/Adapter_Finder.php

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