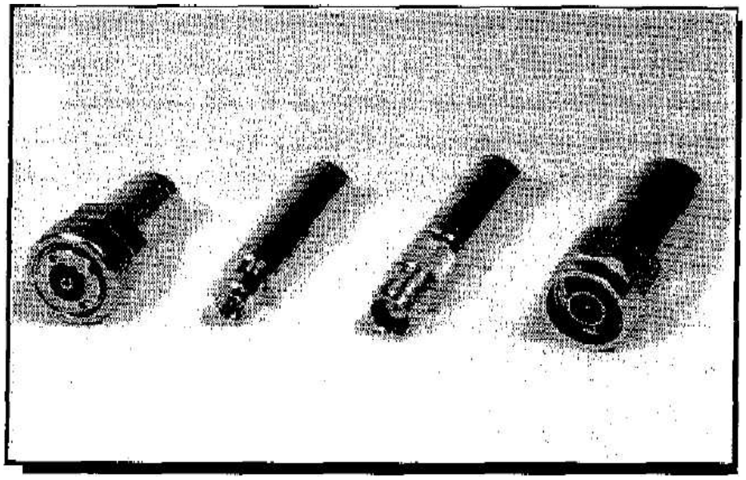
# VERIFYING VANA SOURCE MATCH USING COAXIAL OFFSET SHORTS

MARCH 1990



**A sampling of the 2.498 cm offset shorts available from Maury Microwave.**

## INTRODUCTION

In the measurement of complex reflection coefficient using a VANA (Vector Automatic Network Analyzer) there are three significant errors that can affect measurement accuracy. These are:

* Directivity
* Reflection frequency response tracking
* Source match

The one-port calibration of the VANA measures these errors and stores them for subsequent vector correction of the measured device-under-test (DUT) reflection coefficient.

Effective source match, i.e.: the residual source match error after the VANA is calibrated, is an accuracy consideration in the measurement of medium to high reflection coefficients. This covers a large percentage of practical day-to-day DUT meas-urements.

The purpose of this application note is to describe a method, using just a long offset short, of evaluating effective source match in coaxial measurement systems.

## CALIBRATION

Prior to attempting a measurement of effective source match, the VANA should be carefully calibrated in the most accurate fashion available.

Most VANA's offer several calibration methods. For example: on the HP8510 depressing the CAL key on the menu block brings up the main calibration menu. Selecting either the CAL 1 or CAL 2 softkey from this menu displays the calibration method choices.

"Response" calibrations do not measure and cannot correct for source match error and should not be used to prepare for this measurement.

A two-port calibration (One-Path, Full, or TRL) can be used, but if the purpose of the calibration is a one-port measurement (such as effective source match), a two-port calibration is an unnecessary complication.

Depending upon whether the measurement is to be made on Port 1 or Port 2 of the VANA, the selection should be either "Sll One-Port" or "S22 One-Port".

The traditional one-port calibration technique is referred to as OSL (Open-Short-Load). The equipment required consists of a metrology grade sliding load, an open circuit, and a short circuit. The latter two must be characterized for offset length (the electrical length between the outer conductor reference plane and the short or open plane). In addition, the capacitance coefficients of the open must be known.

These components and those required for a complete, two-port calibration are provided in all Maury high precision VANA calibration kits. The kits also provide the characterization data, such as the open capacitance coefficients, in media (floppy diskette or tape cartridge) appropriate for a specific network analyzer.

Maury manufactures VANA calibration kits for all popular coaxial connector series and VANAs, and in several price ranges. Table 1 is a listing of the model series for the most popular connectors, A model letter suffix designates the applicable VANA (Wiltron 360, HP8510, 8720, etc.) and the caliber of the kit (basic, expanded, high precision, etc.). Maury also manufactures a full line of waveguide calibration kits.

| MODEL SERIES | CONNECTOR |
|---|---|
| 2650 | 7mm |
| 8050 | 3.5mm |
| 8650 | TNC |
| 8850 | Type N |

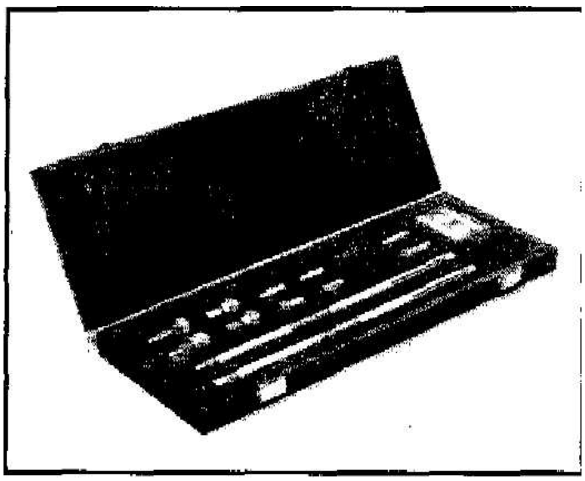


Figure 1. The Maury 8650E Precision TNC Calibration Kit for the HP8510.

Once the VANA is calibrated for a one-port measurement, the error terms are stored in memory, and subsequent measurements are corrected in accordance with the error model. The general question is, how good is the calibration? The remainder of this application note will be devoted to evaluation of one of the one-port measurement errors: the effective source match.

## VERIFICATION OF SOURCE MATCH

Verification refers to the process of measuring the effective source match error. There are several means of doing this; however, the simplest and most effective method is to measure the S11 of a long offset short after the VANA has been calibrated.

If the effective directivity is considered perfect, then the effect, as seen from the reference point of the short, is to cause the source match vector to rotate around the tip of the short vector as the frequency changes. This is illustrated in Figure 2.

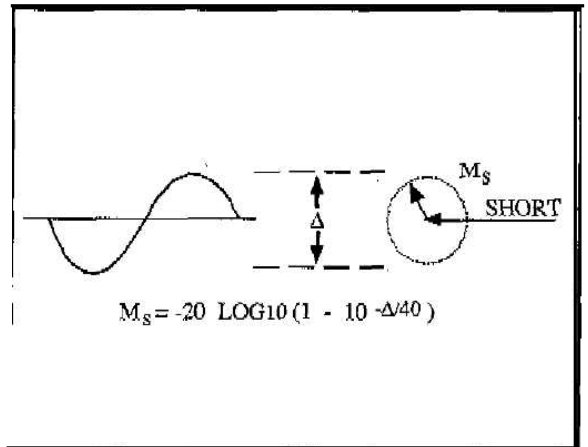



Figure 2. Trace ripple in a Sll plot due to rotation of the source match vector.

Note that if the effective source match were perfect, the output display would be a straight line. The rotation of the source match vector and its finite size give rise to a ripple in the plot of Sll versus frequency. The peak-to-peak magnitude of the ripple, therefore, is a measure of the effective source match as shown by the equation in Figure 2. For convenience, this equation is plotted in Figure 3.

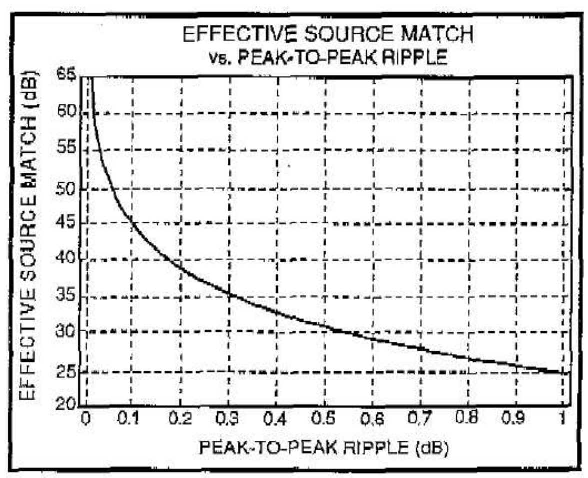



Figure 3. Plot of effective source match versus peak-to-peak trace ripple.

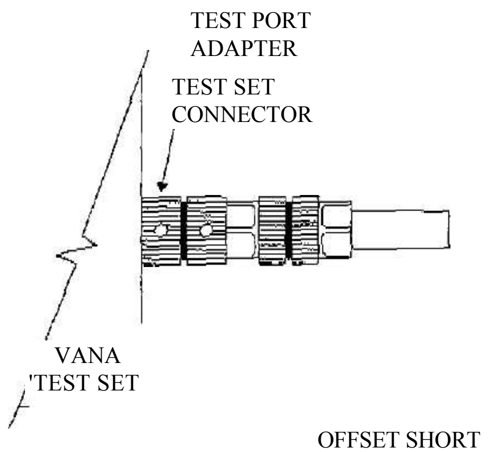



**Figure 4. Set-up for measuring effective source match.**

The measurement is quite simple, and the procedure is as follows:

Step 1.
Calibrate the analyzer for a One-port measurement over the frequency range of interest.

Step 2.
Connect the equipment as shown in Figure 4, Note the use of a Test Port Adapter to reduce wear and tear on the test set connector and avoid costly repair bills (see Table 2).

Step 3.
Set the measured parameter to S11.

| | |
|---|---|
| Depress the S11 key in the Parameter control block. | WILTRON 360 Depress the S-Parameters key in the Display control block. Use the on-screen Menu cursor/Enter keys to select S11. |

Step 4,
Set the display format to Log Magnitude.

| | |
|---|---|
| Depress the LOG MAG key on the Format control block. | WTLTRON 360 Depress the Graph Type key on the Display control block, and use the Menu cursor/Enter keys to select LOG ' MAGNITUDE. |

Step 5.
Set the Reference position to the center of the scale.

| | |
|---|---|
| Depress the REF POSN key on the Response control block. | WILTRON 360 Depress the SET SCALE key on the Display control block, and use the Menu cursor/Enter keys to select REFERENCE LOCATION. |
| Depress 5, XI in the Entry control block. | Use the control knob to set the reference line indicator to the centerline of the vertical scale. |

Step 6.
Set the value of the reference line to 0 dB,

| | |
|---|---|
| Depress the REF VALUE key in the Display control block. | WILTRON 360 Use the on-screen Menu cursor/ENTER key to select REF VALUE. |
| Depress 0, X1 in the Entry control block. | Depress 0, X1 in the Entry control block. |

Step 7.
Adjust the scale resolution such that the ripple is measurable.

| | |
|---|---|
| Depress the SCALE key in the Display control block. | WILTRON 360 Use the on-screen Menu cursor/ENTER key to select RESOLUTION. |
| Depress 0-05, X1 in the Entry control block. | Depress 0.05, X1 in the Entry control block. |

NOTE: This sets the on-screen resolution to 0.05 dB/division and is suggested as typical. Higher resolution may be used; however, trace noise may interfere with accurate location of the peaks and troughs of the display.

Step 8.
Measure the maximum peak-to-peak ripple in dB on the analyzer display. The delta Marker mode is quite useful for this purpose.

Step 9.
Use Figure 3 or the equation in Figure 2 to determine effective source match.

A typical VANA display of a S11 measurement of a 2,498 cm offset short is shown in Figure 5. This result was obtained after a standard OSL calibration using a sliding load. The test port connector was type N female. The worst case peak-to-peak ripple of about 0.06 dB can be read directly from the display. Using Figure 3, the effective source match can then be determined to be about 49 dB.

In principle, the effective directivity vector also rotates around the tip of the effective source match vector. Note that this procedure assumes perfect directivity. Obviously, this is an invalid assumption; however, with most analyzers using a high quality calibration kit. the residual directivity error is at least an order of magnitude less than the effective source match and is generally ignored in most measurements.

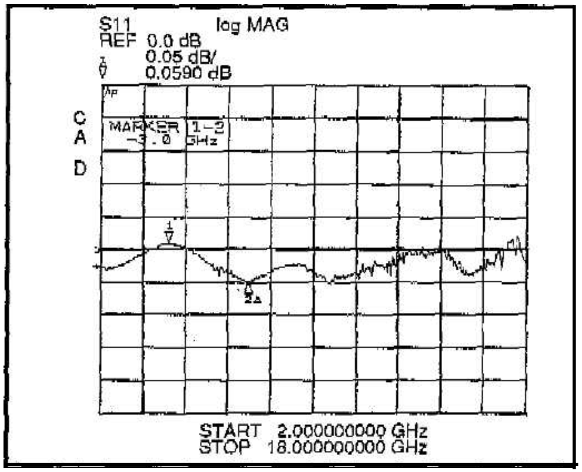



Figure 5. Sll (Log Magnitude) plot of a 2.498 cm offset short (7mm connector).

Maury Application Note 5C-026 describes a method of eliminating even this small error from the effective source match measurement.

| TABLE 2<br>MAURY TEST PORT ADAPTERS | | |
|---|---|---|
| MODEL NUMBER | CONNECTORS | |
| | FROM | TO |
| 2633A | APC7F | APC7 |
| 2633B | NMD3.5 (f) | APC7 |
| 8009A | NMD3.5 (f) | APC3.5 (f) |
| 8009B | NMD3.5 (f) | APC3.5 (m) |
| 8619A | NMD3.5 (f) | TNC (f) |
| 8619B | NMD3.5 (f) | TNC (m) |
| 8829A | NMD3.5 (f) | N (f) |
| 8829B | NMD3.5 (f) | N (m) |

## OFFSET LENGTH

Development of the ripple pattern requires that the magnitude of the resultant vector sum of the short and effective source match reach both extremes, maximum and minimum, over the frequency band of interest. One immediate thought then would be to use a very long length of line, say 10 centimeters, connected to a fixed (nominally, zero offset) short.

There are two problems with this approach. It requires two coaxial connections which could deteriorate the quality of the short and introduce additional discontinuities. More importantly, as the length of line increases so does the dissipative loss. The loss would introduce a slope to the ripple pattern making it difficult to accurately determine the ripple envelope.

Coaxial measurements are usually made over broad frequency ranges - 2 to 18 GHz for example, would be typical. For such a measurement it is only necessary for the offset length to be 1/4 wavelength at or near the lowest measurement frequency.

The plot in Figure 5 was obtained with a 2.498 cm (1/4 wavelength at 3 GHz) offset short. Note that the ripple pattern can be easily extrapolated at least down to 2 GHz even though at this frequency the offset length represents about 0.17 wavelength.

For higher frequency measurements over large bandwidths Smaller offset lengths can be used to further reduce the effect of line loss. For example, if the measurement frequency range is 6 to 18 GHz, an offset length of 1.249 cm (1/4 wavelength at 6 GHz) will work quite well.

As can be seen, selection of offset length for broadband applications reduces to determining which standard offset is 1/4 wavelength (or slightly less as noted above) at the lowest measurement frequency. Larger offsets will make the ripple envelope easier to detect; however, the pattern distortion caused by line loss could introduce reading errors and may reduce measurement resolution.

In general, the "A" models noted in Table 3 below - offset length of 2.498 cm, - have been found to work quite well over the 2 to 18 GHz range, as do the "B" models - offset length 1.249 cm. - from about 4 to 26.5 GHz.

Maury Microwave manufactures a line of offset shorts that provide a range of offsets in several coaxial connector series ideally suited for this purpose. These are listed in Table 3,

| TABLE 3<br>MAURY OFFSET SHORTS | | | | | | |
|---|---|---|---|---|---|---|
| Offset Length (cm) | | 2.498 | 1.249 | 0.735 | 0.526 | 0.337 |
| $\lambda$/4Freq. (GHz) | | 3.00 | 6.00 | 10.20 | 14,25 | 22.24 |
| CONNECTOR | 14mm | 2449A | 2449B | | | |
| | 7mm | 2649A | 2649B | 2649C | 2649D | |
| | 3.5 mm (f) | 8046A | 8046B | 8046C | 8046D | 8046E |
| | 3.5 mm (m) | 8047A | 8047B | 8047C | 8047D | 8047E |
| | TNC (f) | 8606A | 8606B | 8606C | 8606D | |
| | TNC (m) | 8607A | 8607B | 8607C | 8607D | |
| | N(f) | 8806A | 8806B | 8806C | 8806D | |
| | N (m) | 8807A | 8807B | 8807C | S807D | |
| | | MAURY MODEL NUMBERS | | | | |

## SUMMARY AND CONCLUSIONS

Effective source match (the residual source match error of a VANA after it has been calibrated) can be a significant source of error in VANA measurements - particularly, reflection coefficient. Effective source match can be measured quite easily over broad frequency ranges using an appropriate offset short available from Maury Microwave.