Impedance Characteristic Evaluation of SMD by Using the ENA with Inter-Continental Microwave (ICM) Test Fixture

Application Note 1463-5

Agilent Technologies

Introduction

With the trend of wireless communications and digital equipment operating at higher frequencies, the need to evaluate RF components under higher and wider frequencies is becoming increasingly important. Generally, an RF impedance analyzer is used for impedance measurement up to 3 GHz; however, beyond this frequency range, a network analyzer is commonly used. The network analyzer is a convenient instrument for measuring impedance over a wide frequency range, but measurement accuracy is degraded in comparison with the RF impedance analyzer[1]. This application note describes impedance characteristic evaluation of SMD by using the ENA RF network analyzer with the ICM test fixture. In addition, we also explain the TRL calibration procedure using the ENA with ICM test fixture (TF-3001-S), special considerations for measuring surface-mount devices (SMD), and impedance characteristic evaluation using the impedance parameter display software.

1. For information on the comparison between an impedance analyzer and a network analyzer, refer to reference application note 1369-2

TRL Calibration Procedures

This section describes the TRL Calibration procedure using the ENA, ICM test fixture (TF-3001-S), and TRL calibration kit (TRL-3004B).

Figure 1 shows the ICM test fixture mainframe (TF-3000 Series) and the calibration kit (TRL-3004B).

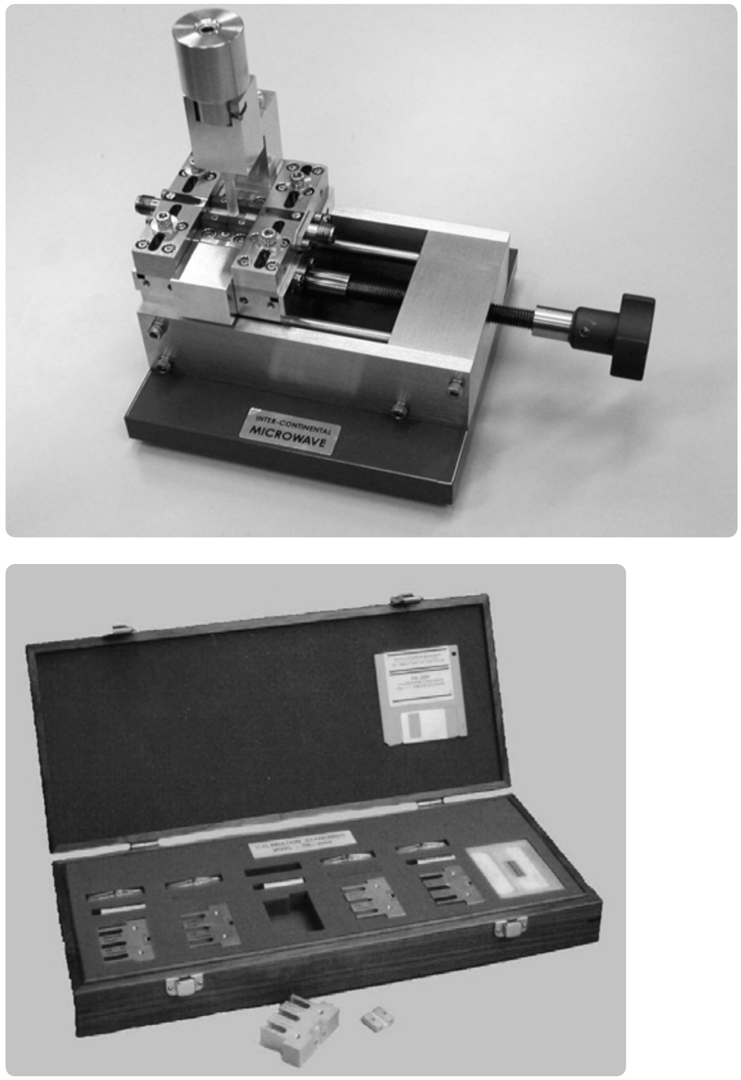

Figure 1. Test fixture mainframe (TF-3000 Series) and calibration kit (TRL-3004B)

Step 1. Setting of the ENA

Before performing the TRL error correction, basic measurement parameters such as test frequency range, IFBW, power level, and measurement points should be set in advance. Please note that if you change measurement parameters such as test frequency range after performing error correction, the calibration data will be changed to compensation data, and this may degrade measurement accuracy. In the case of the ENA, once calibration data is changed to compensation data, status display “C”, which is located on the bottom-right corner of the screen, will be changed to “C?”.

Step 2. Define the calibration kit

To ensure an accurate calibration, it is very important that the standard coefficient of the calibration kit (TRL-3004B) be entered in the ENA. The standard coefficient is provided with the calibration kit and each data item should be entered correctly. Table 1 shows examples of standard coefficient definitions.

Table 1. Examples of standard coefficient definitions (TRL-3004B)

Standard		Fixed or sliding	Offset			Frequency (GHz)		Standard label
No.	Type		Delay ps	Z_0 Ω	Loss GΩ/s	Lower	Upper	
1	Short (Reflection)	Fixed	-77	50	0	0	999	Short
2	Thru	Fixed	0	50	0	0	999	Thru
3	Delay (Match)	Fixed	1	50	0	0	0.501	Match
4	Delay (Line)	Fixed	119	50	0	0.499	3.7	Line 1
5	DELAY (Line)	Fixed	16	50	0	3.49	26.6	Line 2

Launch the TRL/LRM calibration software and choose the test port for measurement (Figure 2). Then push the **[Define CalKit]** button to launch the standard coefficient input screen, which is shown in Figure 3. The each standard coefficient can be easily defined into the ENA through this menu. Although this software also supports both the LRM and TRM calibrations, in this application note we explain the TRL calibration as an example.

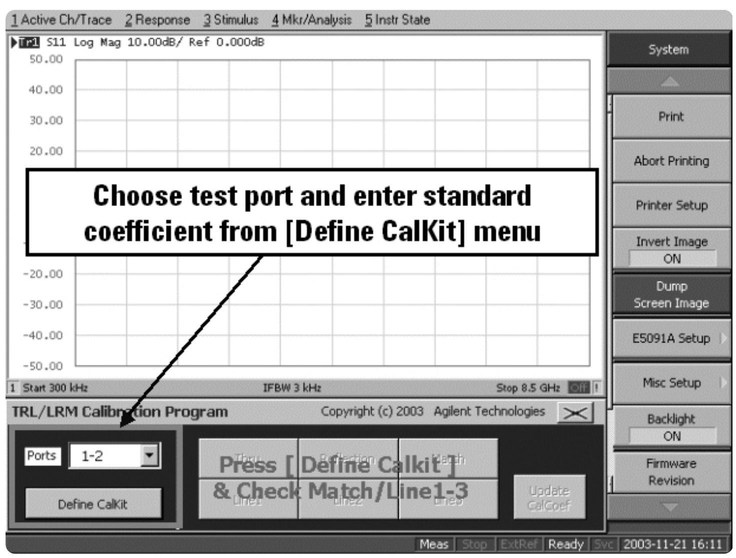

Figure 2. Define CalKit menu

The standard coefficient defining procedure is explained based on Figure 3.

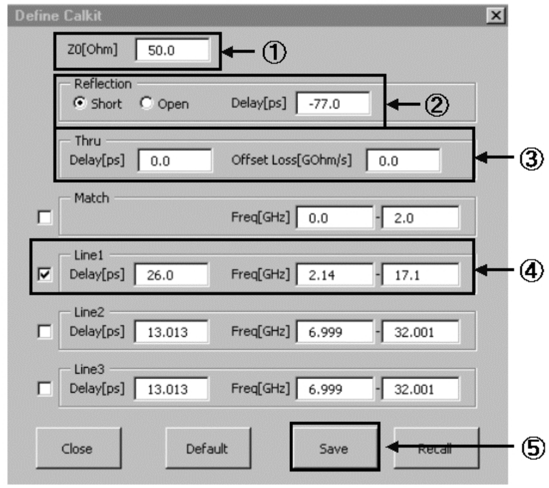

Figure 3. Standard coefficient input screen

❶ **Define the system impedance Z0:** Z0 is defined as 50.0 Ω.
❷ **Define the Reflection:** The TRL-3004B uses a Short as the Reflection standard, so the Short is chosen and the Delay of Short is defined as -77 psec.
❸ **Define the Thru:** The Delay of the Thru is defined as 0 psec, and the Offset Loss is defined as 0 GOhm/sec.
❹ **Define the Line:** The TRL calibration uses multiple lines because the usable bandwidth of a single Thru/Line pair is limited by the TRL calibration 1:8 (frequency span:start frequency) guideline. The phase shift between the Thru and the Line must be between 20 deg and 160 deg. The TRL/LRM calibration software supports 3 Line standards, and this example performs TRL error correction by using one of these lines. In the case of Figure 3, Line 1 is chosen and the Delay is set to 26.0 psec. Also, the test frequency range is set from 2.14 GHz to 17.1 GHz.
❺ Save the standard coefficient: After each standard coefficient is defined, each standard should then be saved in the ENA with the **[Save]** button of TRL/LRM calibration software.

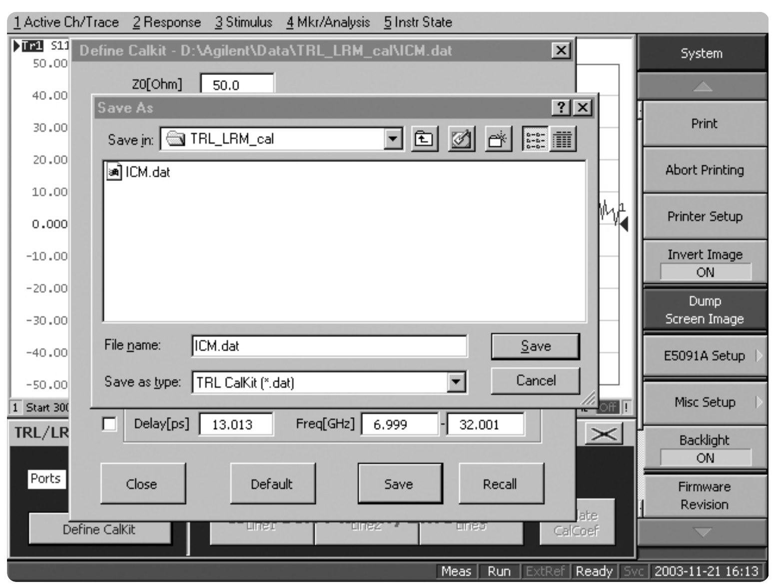

Figure 4. Save the standard coefficient of TRL calibration

Step 3. Perform TRL error correction

The TRL calibration is next performed. Connect each calibration standard (Thru, Reflection, Line) to the test fixture and then push the button that corresponds to each calibration standard. After error correction is finished, a "v" mark appears in the check box on the button. Then the next standard needs to be measured (Fig. 5).

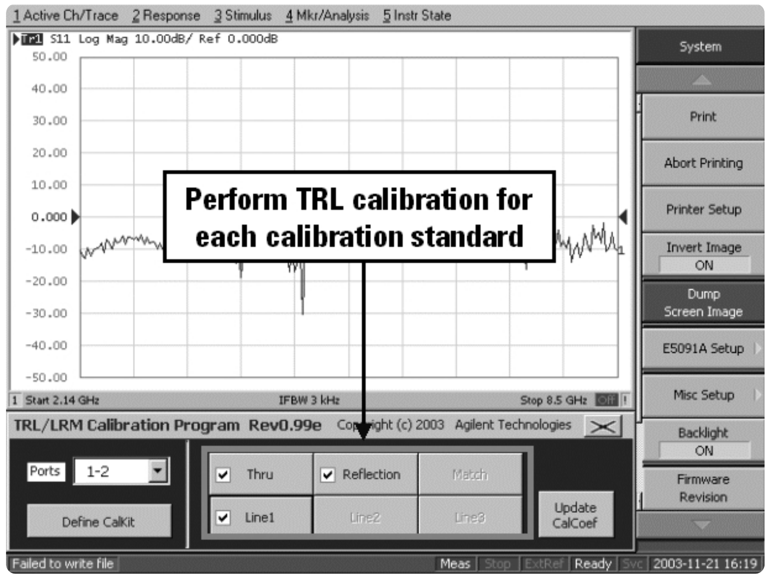

Figure 5. Performing TRL calibration

After all error corrections are performed, calibration coefficients must be stored into the ENA by using the **[Update CalCoef]** button.

Step 4. Verification of TRL calibration

Before performing actual measurements, it is important to verify the calibration. This section explains how to verify the calibration performance by using the Line standard. After each calibration, set the measurement display as shown in Figure 6 and measure the S-parameters of the Line. Basically, the Line can be seen as an ideal transmission line, so it does not have transmission loss and the port impedance is very close to 50 Ω. If the TRL calibration is performed correctly, the S-parameter measurement result of the Line can be obtained as shown in Figure 6.

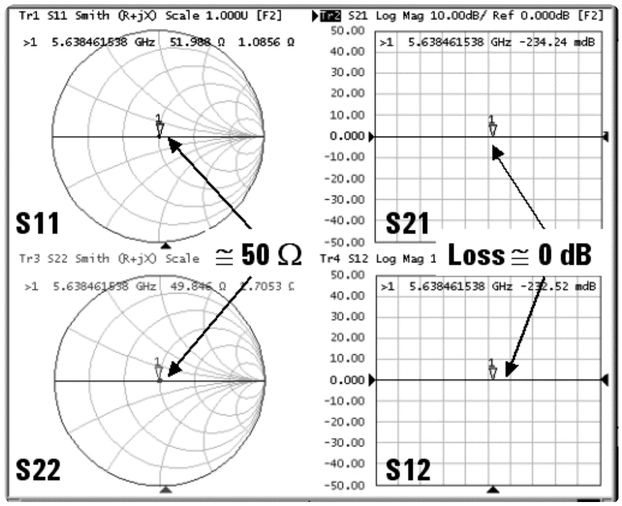

Figure 6. S-parameter measurement result of the Line

If the measurement result shown in Figure 6 cannot be obtained, then most likely the calibration kit will not be defined correctly and the TRL calibration will not be performed properly.

Measurement Procedure of SMD

This section describes impedance measurements of SMD by using the ENA and ICM test fixture with the impedance parameter display software.

Impedance parameter display software

The ENA is supplied with impedance parameter display software (Fig. 7). This software calculates impedance parameters such as |Z|, Cp, Ls, Q, R, and X from S-parameter measurement results and displays them on the ENA's screen up to three traces at a time.

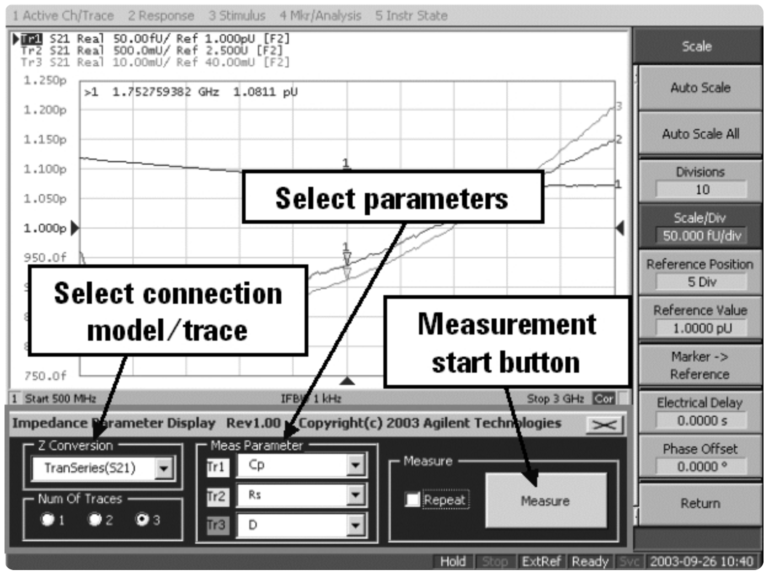

Figure 7. Impedance parameter display software

In addition, as shown in Figure 8, this software works with three different connection models: Series-Thru (TranSeries S21), Shunt-Thru (TranShunt S21), and Shunt-to-GND (Refl S11).

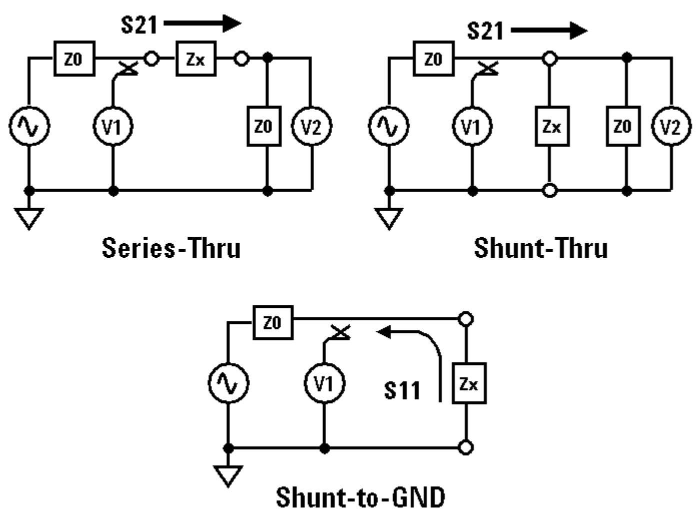

Figure 8. Connection models

In general, the Series-Thru connection model is suitable for high-impedance measurement, while the Shunt-Thru connection model is suitable for low impedance measurement. The Shunt-to-GND connection model is better suited for impedance measurement close to 50 Ω.

Evaluation procedure of SMD

The SMD capacitor (1 pF, size 1005 mm/0402 inch) is measured by using the Series-Thru connection model.

The TF-3000 Series provides three kinds of mid-section adapters: Series-Thru, Shunt-Thru, and Shunt-to-GND (refer to Fig. 7). Also, the TF-3000 Series can be adapted for various kinds of DUT sizes by changing the specialized midsection adapter. Furthermore, changing the midsection does not require re-calibration, so this feature drastically reduces additional engineering work.

Before measuring the SMD, the positioning of the test fixture needs to be adjusted. The midsection of the TF-3000 Series holds the SMD with a push rod (white circle in Fig. 9 inset). If this positioning is not adjusted properly, the contact between the device and the fixture's electrode becomes unstable, which may cause scattered measurement results.

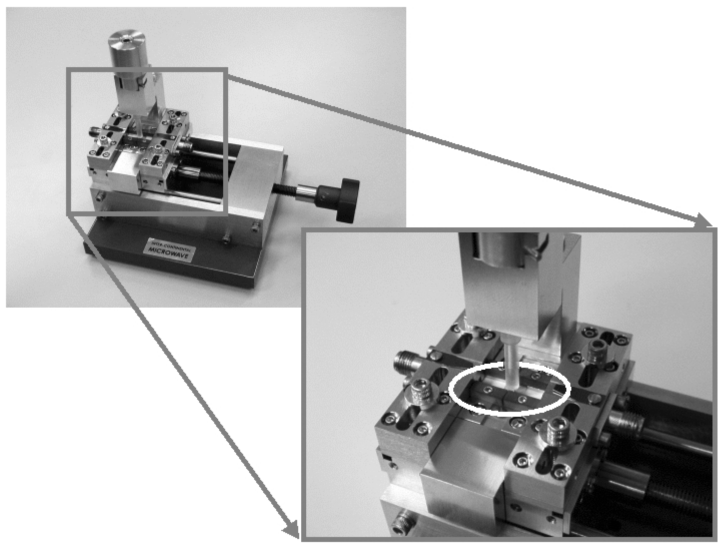

Figure 9. Midsection adapter

In this evaluation, the 1005 mm/0402 inch shorting device provided by Agilent (P/N: 16191-29005) is used to confirm the contact condition between the device and the test fixture's electrode.

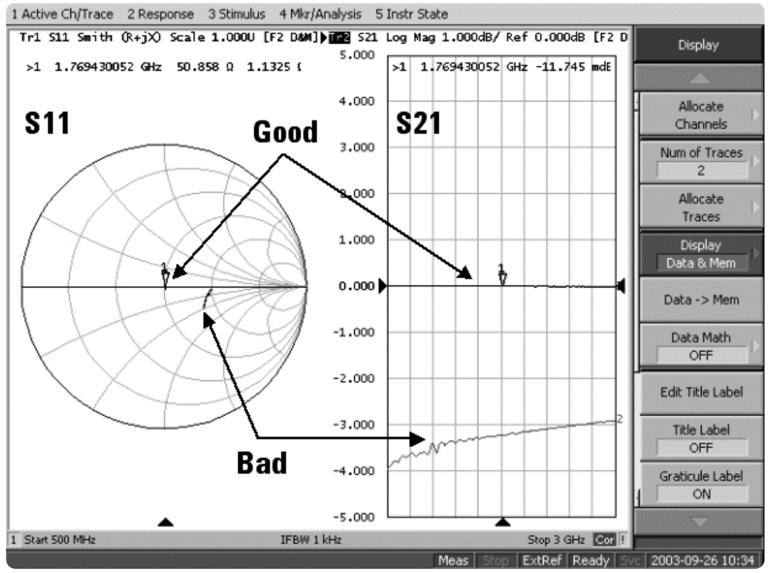

Figure 10. Confirmation of device contact condition

Figure 10 shows examples of both good (dark color) and bad (light color) contact conditions. Here, a shorting device is measured with the Series-Thru connection model, so almost the same results as a transmission line measurement can be obtained. If the device contact is poor, transmission loss becomes large and impedance is away from 50 Ω.

In the next step, the SMD capacitor is measured. As shown in Figure 10, when the capacitor is measured with the Series-Thru connection model, impedance of the capacitor becomes high in the low-frequency range and the transmission signal is attenuated. As a result, the Smith chart indicates the open condition. On the other hand, in the high-frequency range, impedance of the capacitor becomes low and the transmission signal is not attenuated. Consequently, the port impedance value comes near 50 Ω and the measurement trace moves to the center of the Smith chart.

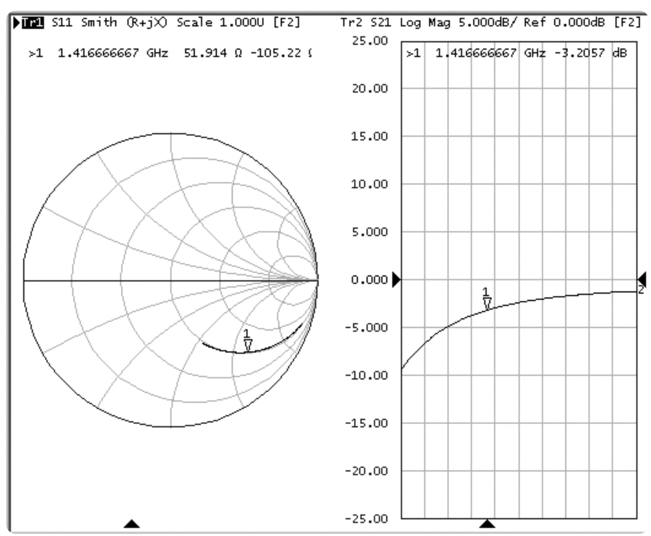

Figure 11. SMD capacitor measurement (1pF, size 1005 mm/0402 inch)

This process is very important for confirming whether the measurement of the device can be done precisely while giving consideration to the behavior of the device; furthermore, it is a key step in performing accurate measurements.

After confirming the measurement result, impedance parameters can be extracted by using the impedance parameter display software.

Measurement using the impedance parameter display software

Launch the impedance parameter display software and select the Series-Thru connection model from the **[Z Conversion]** menu. Then choose the measurement parameters from the **[Meas Parameter]** menu. The impedance measurement can be performed by pushing the "Measure" button in the **[Measure]** menu. If repeatable measurement is required, enable the "Repeat" check box at the right side of the "Measure" button. Figure 11 shows the measurement results for an SMD capacitor using the impedance parameter display software.

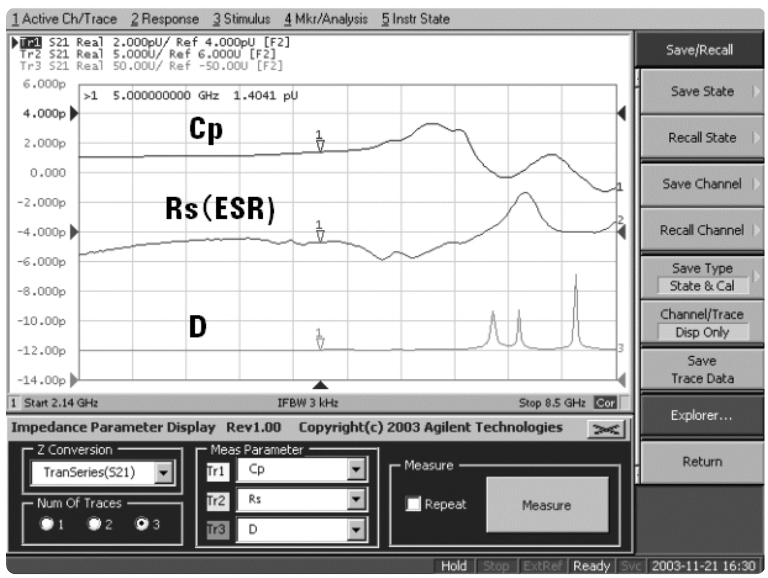

Figure 12. Measurement results of SMD capacitor using impedance parameter display software

In this example, common parameters of capacitor evaluation, such as Cp, ESR, and D, are measured up to 8.5 GHz. The measurement result for the device varies with the connection model of the test fixture, depending on whether it's Series-Thru, Shunt-Thru, or Shunt-to-GND. Therefore, it is important to define not only the instrument used but also the test fixture's connection model when comparing the measurement values of devices.

Conclusions

This application note describes the SMD measurement procedure by using the ENA RF network analyzer with the ICM test fixture. The TRL calibration and actual SMD measurement procedures are also explained. We hope this application note is useful for engineers as they evaluate RF components using the ENA with ICM test fixtures.

References

ENA 2, 3 and 4 Port RF Network Analyzers,
Product overview, Literature number 5988-3765EN

Advanced Impedance Measurement Capability of the RF I-V Method Compared to the Network Analysis Method, Application Note 1369-2,
Literature number 5988-0728EN

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