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Correlating Impedance Measurements Among Different Types of Measurement Instruments



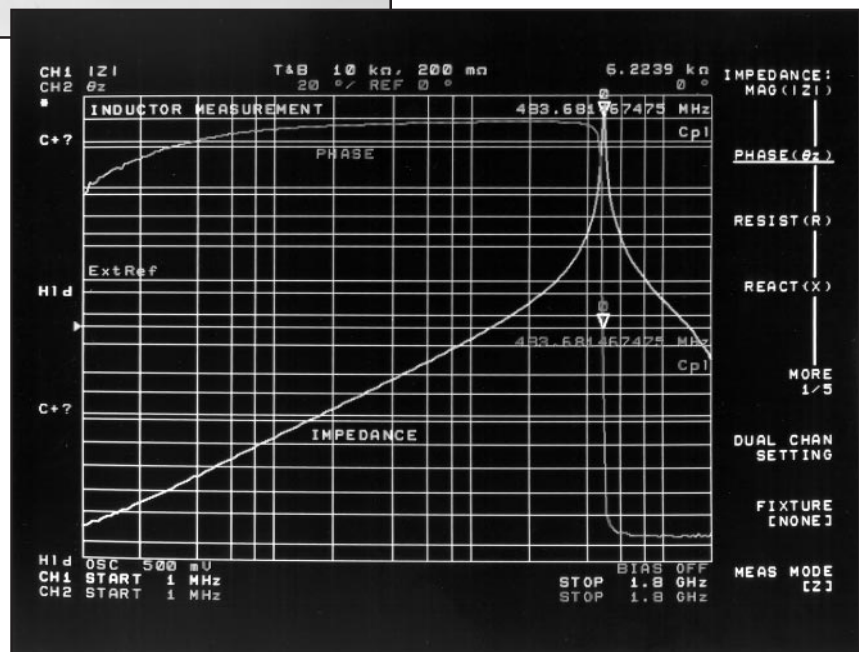
Product Note 4291-4

HP4291B RF Impedance/ Material Analyzer



Introduction

As the technology of impedance measuring instruments advances, problems correlating measurements between instruments, instrument configurations, and even instrument platforms become common. The factors affecting the correlation of impedance measurement values and the attention to be paid for achieving higher measurement correlation are studied by making an example of HP 4291B RF impedance/material analyzer and HP 4191A RF impedance analyzer in this product note.



Factors affecting correlation

It is desirable to get the same results when a device is measured by any instrument. However, there is always some difference between measurement instruments. The fundamental difference is a result of the instrument's specified accuracy. The measurement accuracy is specified at the calibration plane of the instrument. This plane is defined by calibration standards, and, in the case of the HP 4291B and the HP 4191A, is defined at the 7mm (APC-7) test port. If the device under test (DUT) is measured at the calibration plane (requires an insertable device), the measurement values are only affected by the specified measurement accuracy, thus there is no correlation problem among different instruments (refer Figure 1).

Since most DUTs are non-insertable (do not directly attach to the 7mm connector) at the calibration plain, a test fixture is usually used to contact the device. There are various error factors associated with fixtured measurements, caused by the existence of the test fixture (refer Figure 2). The factors affecting the correlation are discussed as follows.

1. Performing compensation

When a fixtured measurement is made without compensating for the electrical characteristics of the test fixture, the measurement result reflects the characteristics of the DUT as well as the characteristics of the test fixture (fixture parasitics). Several compensation functions are used to remove the error caused by a test fixture. Since different compensation functions are sometimes provided with different instruments, the correlation of measurement values will be affected.

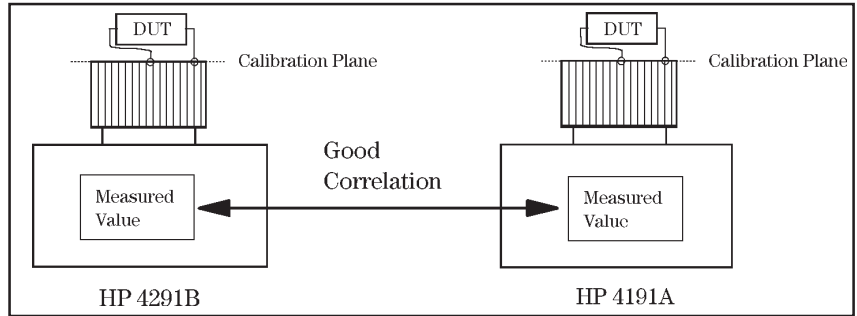


Figure 1. Measuring DUT at Calibration Plane

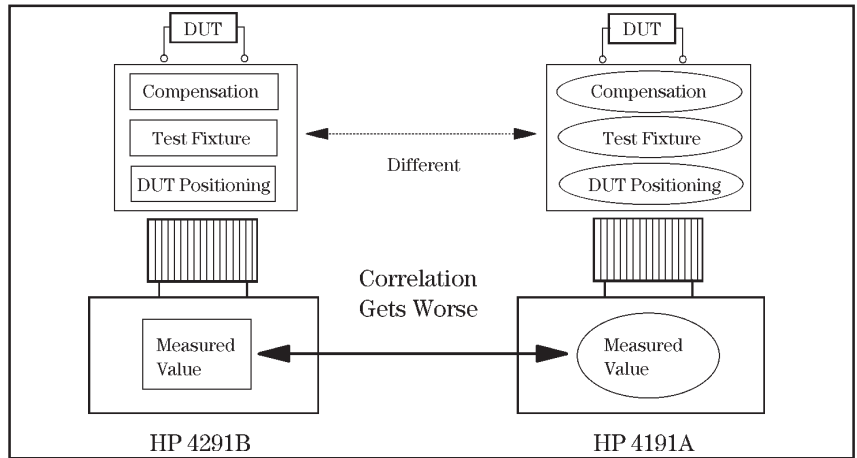


Figure 2. Factors to Affect Correlation Problem

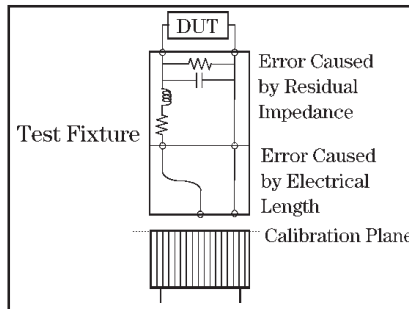


Figure 3. Residual Error Model of Test Fixture

Figure 3 shows the error model caused by a test fixture. There are 2 types of error, one is residual impedance error and the other one is electrical length error. The residual impedance which includes small resistance, inductance, conductance and capacitance makes the measurement value inaccurate. The electrical length error occurs due to a phase shift of the test signal along the 50Ω transmission line between the

calibration plane and the DUT. This leads to an impedance measurement error when measuring phase. Residual impedance and phase shift error can be compensated with OPEN/SHORT compensation and electrical length compensation. The HP 4291B provides both OPEN/SHORT/(LOAD) compensation and electrical length compensation functions. All error factors mentioned above can be removed effectively. As a result, the real characteristics of a device can be measured, since the device can be equivalently moved to the calibration plane (Figure 4). (Remarks: Strictly speaking, one factor still remains. This factor is regarded as the time fluctuation of compensated values). The HP 4191A provides only the electrical length compensation function (Figure 4(b)). Since the measurement value includes the impedance of the DUT and the test

fixture, while the HP 4291B compensates for the fixture parasitics, there exists a problem in correlating between these measurement platforms. In order to achieve HP 4291B equivalent compensation when using the HP 4191A, we need to do some work to remove the residual impedance error from the measurement results of HP 4191A. This can be accomplished by computing the OPEN/SHORT compensation values using a program through an external computer.

2. Test fixture

Even though we perform the OPEN/SHORT compensation and electrical length compensation mentioned above, we sometimes obtain different measurement values when using different types of test fixtures. The shape of electrodes, contacting pressure of electrodes, structures around the device, etc. can be considered as the reasons.

Shape of electrode

The shape of the electrode can be divided into 2 types. These are the point-contact type and the surface-contact type, and are described according to how the electrodes make contact with the DUT. When the electrodes of the DUT, which contact the fixture electrodes, are flat, as is the case with a surface mount device (SMD), there are advantages to either type. The point-contact type allows each of the fixture electrodes to contact a specific point on each electrode of the DUT. This reduces the chance that a slight change in placement of the DUT on the fixture would affect the measurement result. The surface contact type has the advantage that the interface between the DUT and the fixture better approximates the use conditions of the mounted SMD DUT. Proper, careful use of the surface-contact type fixture is required to minimize the chance that DUT placement will effect the measurement result.

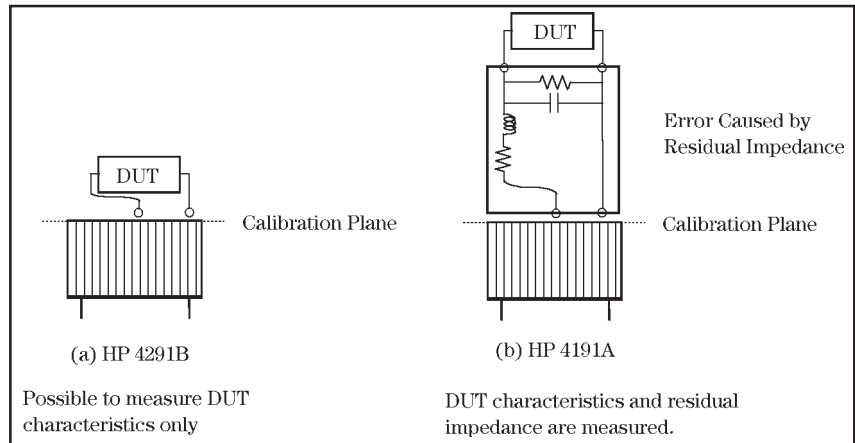


Figure 4. Measurement Value Differences caused by Different Compensation Techniques

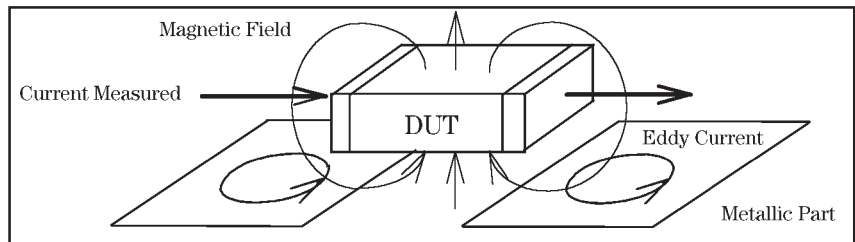


Figure 5. Eddy Current

Contacting pressure of electrode

The measurement values are sometimes affected by slight changes in contact impedance. The contact impedance at each electrode interface should be considered when attempting correlation. Repeatable measurements can only be made where contact impedance is repeatable. A two electrode DUT should be connected to the fixture so that the contact impedance at each electrode interface is the same. Clean, flat surfaces and adequate pressure are important.

Surrounding structure of DUT

The test signal current flowing through the DUT develops a magnetic field around the DUT, especially in the case of inductor measurement. When a conductive material is near the DUT, the magnetic field induces eddy currents in that material. These currents work to prevent the magnetic field (Figure 5). The loss due to the eddy current affects measurement error. A fixture that does not place any conductive

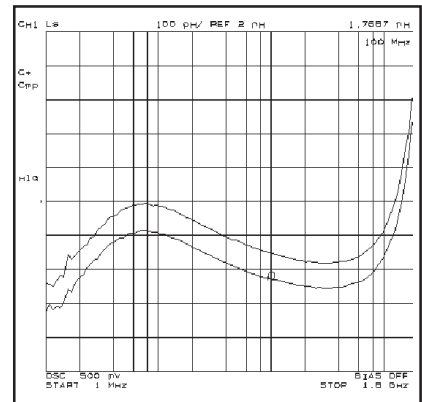


Figure 6. Difference of Measured Results caused by DUT Positioning

materials near where the DUT is placed should be used. For example, RF fixtures such as the HP 16191A, the HP 16192A, the HP 16193A are designed with Teflon material near the DUT. This helps to minimize eddy current loss.

3. Positioning DUT

When using the same fixture, the measured impedance value may

change slightly if the technique for connecting the DUT is not repeatable (position, pressure, etc.). A change in the test signal path across the DUT due to a non-uniform current distribution within the conductor of the DUT causes a slight change of voltage drop or phase shift inside the DUT. This phenomenon is termed the "skin effect", and is the reason that positioning of the DUT is critical to repeatable measurements. As an example (Figure 6), a 2nH SMD inductor was measured with the HP 4291B and HP 16192A Test Fixture from 1MHz to 1.8GHz. The DUT was moved about 0.3mm vertically against the axis of the fixture. Figure 6 shows the measurement results. Approximately 100pH difference was observed at maximum. For stable low impedance measurements, it is essential to contact the DUT electrode and the fixture electrode at the same location for each measurement. As a solution, many test fixtures are equipped with a guide to fix the DUT location.

Conclusion

Correlation of measurement systems has always been a burden in industry. The ability to verify test results is dependent on the variety of factors detailed above, but especially on effective communication between the technicians operating each instrument. When correlating between measurement systems, each system should use the same measurement instrument and fixture, thereby minimizing these error factors.

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