RF Probe Comparison for Characterizing Passive and Active Devices

ABSTRACT

This application note discusses the probe comparison measurement methods and results for both passive and active devices. The comparison for passive devices was undertaken by AIST, the National Metrology Institute (NMI) of Japan. It demonstrated that the TITAN™ Probe T110A-GSG0100 provided identical measurement results as the reference i110-A-GSG-100 probe.

INTRODUCTION

RF Probe technologies have been continually improved for more than 30 years. Drivers for this development are the demand for improved measurement accuracy, data repeatability, and probe lifetime, an increase of measurement frequencies and RF power, operation in a harsh environment, implementation of the new semiconductor and metallization materials in emerging technology devices, tighter integration of consumable products, and minimizing the cost of the test[1].

TITAN™ RF probe from MPI combines a unique set of electrical and mechanical characteristics and ensures unmatched calibration and measurement results over the wide application and frequency ranges. It significantly minimizes the cost of test, providing system operators with unmatched ease of use experience. These motivate RF engineers to integrate TITAN™ Probes into various wafer-level test applications and thus benefit from the most recent progress in the RF probe technology[2].

Often, a transition from the previously used probe technology to the most advanced one involves extensive measurement data comparison campaigns to ensure data correlation for customer products with the previously collected database. Typically, the probe comparison is undertaken in a simplified way: the measurement data of the same reference devices are collected by the reference probes and the test probes and then evaluated for some acceptance criteria. Such an approach does not require additional complex mathematical computations; thus, an average-skilled system operator can execute it. However, it may lead to wrong conclusions as both the reference and the test data series are affected by unavoidable measurement errors that remain unquantified.

The so-called "metrological comparison approach" involves methods to quantify measurement errors and uncertainties of each data series, the reference, and the test. The uncertainties may include data repeatability, contact repeatability errors, calibration standard fabrication errors, calibration method errors, system drift, etc. NMIs use methods and software tools that estimate uncertainties, propagate them through the experimental steps, and visually present data with uncertainties on comparison plots (Fig. 1). Finally, the experimental data can be accurately evaluated with a quantified confidence level (usually 95%).

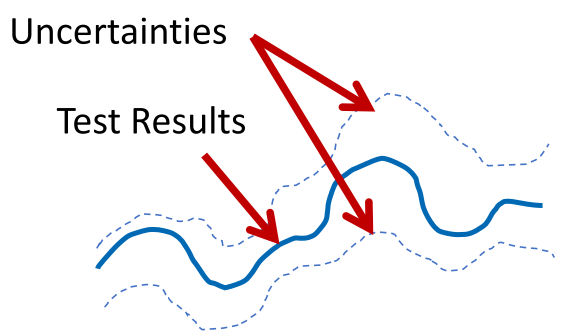

Fig. 1: Data with reported uncertainties.

Fig. 2 compares data from two experiments presented with combined uncertainties. On both graphs, the data series A and B seem to be different. However, the difference between series A and series B on the left graph is within the uncertainty budget on the first graph. That is why we can confidently conclude that both series are identical.

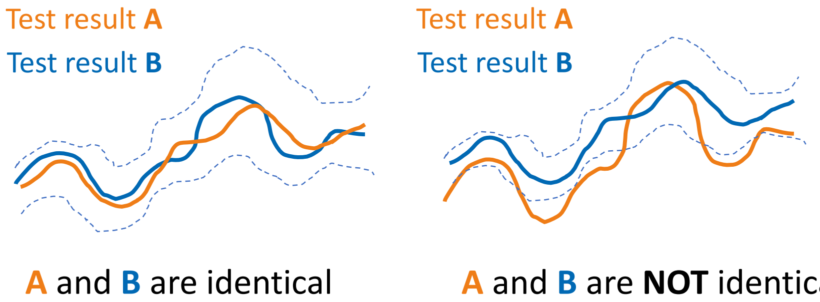

Fig. 2: Comparison of identical (left) and not identical (right) experimental data

Such an approach was used to compare two types of 110 GHz RF probes: the TITAN™ Probe T110A-GSG0100 and the reference i110-A-GSG-100, for the measurement of the reflection and the transmission coefficients of different passive devices. This experiment was undertaken by AIST, the NMI of Japan.

EXPERIMENTAL SETUP AND RESULTS

The AIST experimental system consisted of a semi-automated probe station and a broadband vector network analyzer with a measurement frequency range of 100 MHz to 110 GHz. To increase the measurement accuracy, the intermediate frequency bandwidth of the VNA receiver was set to 100 Hz in the frequency range from 100 MHz to 40 GHz and to 10 Hz for the frequency range from 40 GHz to 110 GHz, respectively. The sweep contained 1100 points. Such a tight frequency step allowed accurate comparison of the results.

The system was calibrated by the multiline TRL calibration algorithm using coplanar calibration standards embedded on the reference calibration substrates. Uncertainties of calibration standards as well other uncertainties were estimated and propagated through the calibration and the error correction procedures using the proprietary software.

Two types of the device under test (DUT) were selected: a mismatched 73Ω coplanar transmission line and a 35dB attenuator. These DUTs represent a wide range of measured device impedances and therefore, S-parameter quantities: from small to large. The probe-tip calibrated reflection and transmission coefficients of the DUTs as well as the estimated measurement uncertainties are presented in Fig. 3.

The experimental results demonstrated that the S-parameters of verification devices are identical when measured by the reference probes and the test T110A-GSG0100 TITAN™ Probes. The calibration residual errors of the reference i110-A-GSG-100 probe and the test TITAN™ Probe are comparable and thus, the data measured by TITAN™ Probe are identical to the data measurement by the reference probes.

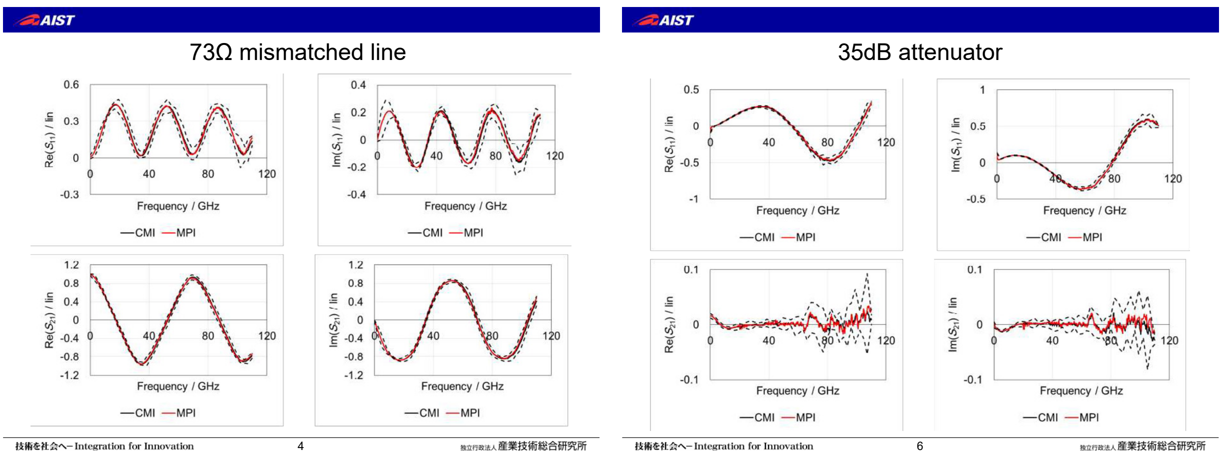

Fig. 3: Comparison of the measured S-parameters with reference i110-A-GSG-100 and the test T110A-GSG0100 probes of the calibrated 73Ω mismatched line and the 35dB attenuator.

COMPARISON FOR ACTIVE DEVICES

In contrast to the passive device characterization, characterization of the active devices includes additional measurement and calculation steps required to de-embed the DUT from its “infrastructure” (contact test pads, feed lines, and via interconnects) and to address bias-dependent device characteristics. The estimation and the propagation of the measurement uncertainties for active devices are much more complex and thus, the metrology-grade data comparison methods for active devices are still on the way.

However, a qualitative comparison can be undertaken for selected device characteristics that are usually sensitive even to small probe-dependent calibration residual errors, such as the Maximum Stable Gain, MSG = |S21/S12|.

Fig. 4 presents a comparison where the MSG of the same transistor was calculated from the corrected S-parameters measured by the reference i110-A-GSG-100 probes and by the test TITAN™ T110A-GSG0100 probes. The data are comparable and thus both probes provided identical device MSG for variable device bias points.

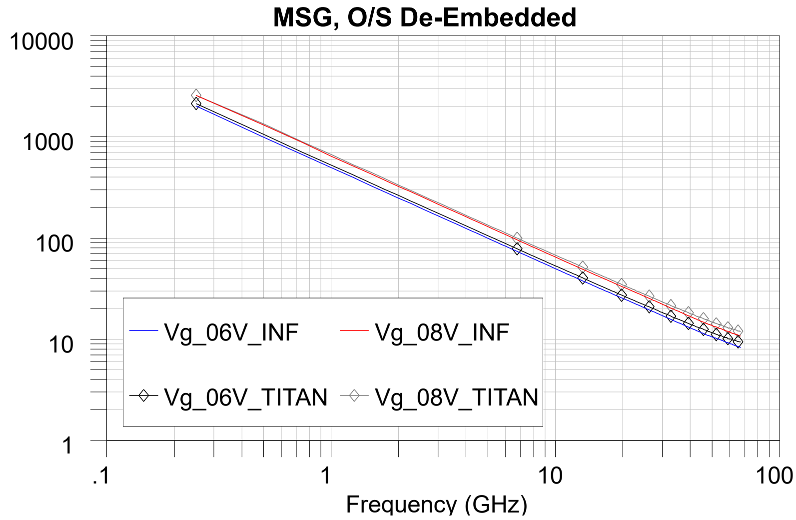

Fig. 4: Comparison of an active device MSG, measured by the reference i110-A-GSG-100 and the test T110A-GSG0100 probes for two device gate biases of 0.6V and 0.8V.

CONCLUSION

Two experiments were undertaken to compare probe-dependent calibration residual errors for characterizing passive and active devices. Both experiments demonstrated that TITAN™ T110A-GSG0100 probes provide results identical to the reference i110-A-GSG-100 probes. The data comparison for passive devices was conducted by the NMI for different types of devices and with an estimation of the experiment uncertainties and the confidence interval. Thus, both probe types can be easily interchanged for similar types of measurements without any concerns. As a result, RF engineers can confidently integrate TITAN™ Probes into various wafer-level test applications minimizing the cost of test, experiencing unmatched ease of use, and achieving unparalleled calibration repeatability and data reproducibility.

REFERENCES

[1] A. Rumiantsev and R. Doerner, „RF Probe Technology: History and Selected Topics,“ IEEE Microwave Magazine, vol. 14, no. 7, pp. 46-58, 2013, doi: 10.1109/MMM.2013.2280241.
[2] „Trendsetting Methodologies for Wafer-Level RF Measurements,“ ed: MPI Corporation, 2017, p. 13.

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