

Improve Device S-Parameter Measurement with Fixture Design and Calibration

This application note describes how to correct and minimize the errors introduced by the test fixture in the measurement of S-parameters of components. The fixture mentioned here consists of a microstrip PCB with SMA connectors. An example based on the MAX2648 5GHz low-noise amplifier is presented.

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[Quick View Data Sheet for the MAX2648](#)
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Measurement Errors

Errors in vector network analyzer (VNA) measurements can be separated into three categories:

- **Drift errors**, which occur when the test system's performance changes after a calibration has been performed;
- **Random errors**, which vary as a function of time.
- **Systematic errors**, which include mismatch, leakage, and system frequency response.

Calibration is the process for removing these errors from network analyzer measurements. To minimize drift errors the test set up should be calibrated with appropriate frequency, and maintained at a constant temperature. Random or noise-like errors are reduced by using a narrow IF bandwidth and by using averaging. Most VNAs include a trace averaging mode that will function over several sweeps to reduce the impact of random errors.

Add Microstrip Devices to Aid in Fixture Calibration

Network analyzers offer the capability to improve accuracy by performing a measurement calibration, this requires the use of a calibration kit in the appropriate connector type, usually coaxial. The device to be measured here has a "non-standard" connector, which a cal kit with coaxial connector is not available. Adding a fixture can meet the requirement of connection between DUT (device under test), a "non-coaxial" connector, and the test equipment interface, a coaxial connector.

An ideal test fixture would provide a transparent connection between the test instrument and the device being tested, allowing direct measurement of the DUT without adding any stray circuits. Since it is impossible to make an ideal fixture, the fixture will introduce additional loss, phase shift and mismatch that can add errors to the measurement of the DUT. The type of calibration required for any particular application will depend solely on how stringent the DUT specifications are.

There are three fundamental techniques for removing errors introduced by a fixture: modeling, deembedding, and direct measurement. This application note describes direct measurement to correct the errors. Direct measurement has the advantage that the precise characteristics of the fixture do not need to be known beforehand. They are measured during the calibration process. The simplest form of direct measurement is a response calibration, which is a form of normalization. A reference trace is placed in memory and subsequent traces are displayed as data divided by memory.

A response calibration only requires one standard for transmission (a thru) and reflection (a short or open), which is done by creating calibration circuits on the same substrate used for the test circuit. First a thru is created which consists of a 50Ω line. The reflect standard can be either an open or short circuited line (50Ω). A short circuit line is chosen for use in this example. The length of the line should be the same as that used for the test circuit, and the short is placed on the reference plane of the measurement. The contact plane between the DUT and the fixture are assumed to be the reference plane. These calibration standards, one "thru" and two "short" for each fixture port, are directly designed on the fixture PCB.

Measurement accuracy is largely dependent upon the calibration standards. The calibration standards thru and short, which are formed with microstrip transmission line whose characteristic impedance is 50Ω , are made on the fixture PCB directly. The precise characteristics of the fixture, especially the accuracy of characteristic impedance of the microstrip and the electrical length of the "thru" and "short", directly determines the measurement's accuracy.

The simplest form of direct measurement is a response calibration. Response calibration has a serious inherent weakness due to the lack of correction for source and load mismatch caused by the error of the characteristic impedance of the microstrip and the coupler/bridge directivity. Mismatch is especially troublesome for reflection measurements. Following is an example fixture that is used to characterize the MAX2648, a LNA (low noise amplifier) operating in the 5GHz to 6GHz frequency range.

Example for the MAX2648

A fixture for characterizing the S-parameters of the Ultra Chip Scale Packaged (uCSP) MAX2648 is shown in Figure 1.

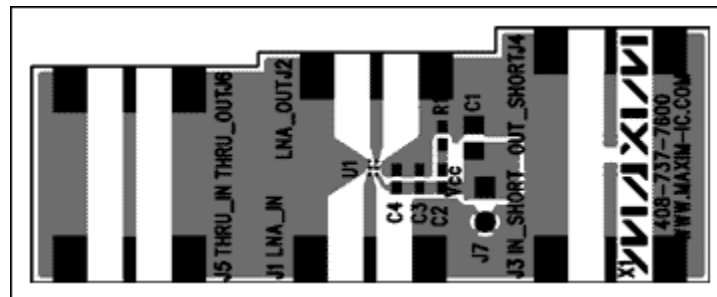


Figure 1. Fixture PCB

Note the microstrip used to route the RF signal from the coaxial connector on the edge of the circuit board to the DUT. Low loss, wide bandwidth coax cables connect the fixture circuit board to the network analyzer. The fixture's microstrip is designed to match both the source and load impedance, assumed to be 50Ω here. Industrial printed circuit board manufacturers typically produce an error in the transmission line impedance of $\pm 10\%$. The characteristic impedance will therefore be between 45Ω to 55Ω after fabrication. With finite errors in the microstrip impedance, it is very important to use a suitable length of microstrip. Two simulation results are shown in Figure 2 and Figure 3 below, which are produced by ADS for 50Ω reflection measurement. Two different line lengths are simulated with a characteristic impedance of 45Ω .

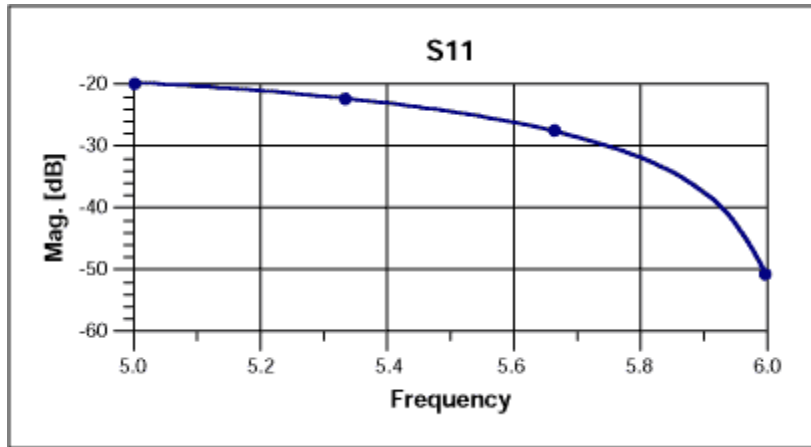


Figure 2. Line length is 1170mil, characteristic impedance is 45Ω reflection measurement result of 50Ω

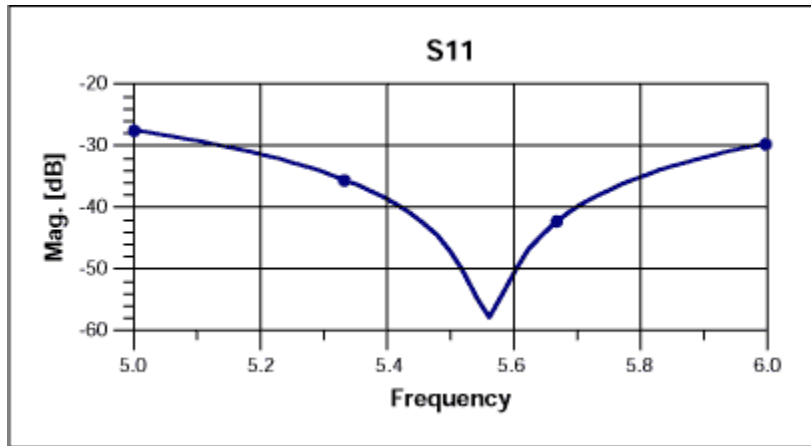


Figure 3. Line length is 630mil, characteristic impedance is 45Ω reflection measurement result of 50Ω

Conclusion

Reflection measurement errors caused by impedance mismatch are reduced to a minimum by selecting the transmission line length. S parameter measurement of a device is aided by designing the test fixture circuit board to incorporate extra transmission lines. These extra lines allow a thru path, and a short circuited reflection path for calibration purposes.

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MAX2648: [QuickView](#)

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