Differential S-Parameter Measurements Using Single-Ended 2-Port Network Analyzer and HL9407 Ultra-Broadband Baluns

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OVERVIEW

In this application note, differential s-parameter measurements using a single-ended 2-port vector network analyzer (VNA) and a pair of HYPERLABS ultra-broadband baluns are compared against measurements taken on a 4-port VNA. The device under test is a broadband differential amplifier. This application note builds on prior work reported in Picosecond Pulse Labs application note AN-21[1]. In the referenced note, Jim Andrews, Ph.D. demonstrated differential s-parameter measurements to 10GHz using PSPL 5310A broadband baluns. Utilizing HYPERLABS' industry-leading broadband baluns, the same technique yields accurate differential s-parameter measurements to 40GHz and beyond from a single-ended 2-port network analyzer.

2-PORT VNA MEASUREMENT SYSTEM

A block diagram of the 2-port measurement system is shown below in *Figure 1*. The VNA is Anritsu MS4644B and the baluns are HYPERLABS model HL9407. These baluns feature -3dB bandwidth from 500kHz to 67GHz, ± 0.1dB amplitude match to 30GHz, and ± 0.3dB amplitude match to 67GHz. Detailed specifications are available from the HYPERLABS web site: www.hyperlabs.com. To improve the impedance match of the differential test ports, HYPERLABS' 10dB attenuators (HL9427-10) are added to each of the four differential test ports as shown in *Figure 1*.

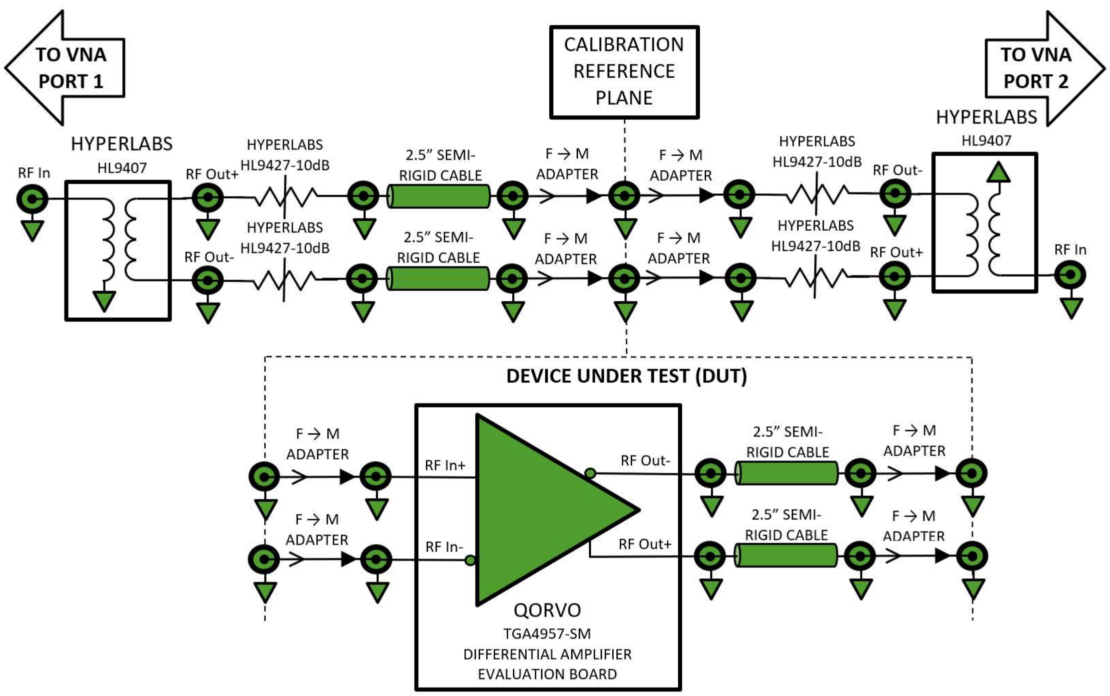

Figure 1: Block Diagram of 2-Port VNA Measurement System Utilizing Two HL9407 Baluns

As shown above, the 2-port VNA Measurement System was constructed with a male differential test port 1 and a female differential test port 2. This arrangement facilitates zero-length thru calibration. The ports of the Device Under Test (DUT) were configured female-male accordingly. The connector spacing of the differential amplifier evaluation board does not match the connector spacing of the HL9407 balun, so it was thus necessary to use interface cables. Short semi-rigid VNA loops were employed to interface the incompatible connector spacings. One set of cables was incorporated into test port 1, and the other set of cables became part of the DUT.

2-PORT VNA CALIBRATION

A 12-Term SOLT calibration was performed including isolation using two Anritsu 3652 “K” calibration kits. Each 3652 kit contains 1 female open, 1 female short, 1 male open, and 1 male short calibration standard. Using two kits, it was possible to simultaneously connect 2 female calibration standards to differential port 1 for each set of Short, Open, and Load reflection calibration.

Figure 2, at the right, shows two female and two male open calibration standards connected to differential test port 1 and differential port 2, respectively. The calibration of port 1 and port 2 was completed simultaneously by cycling through the Short, Open, and Load reflection calibration standards. This approach eliminated the need to swap out equi-phase test port adapters during calibration.

Only one calibration kit’s coefficients could be loaded into the MS4644B VNA. A small calibration error results from minor differences between the two calibration kits. The quality of the resulting calibration is shown below in *Figure 3*, The active 4-port measurement in *Figure 4*, and the defined DUT in *Figure 5*.

Figure 2: Open Reflect Cal of Port 1

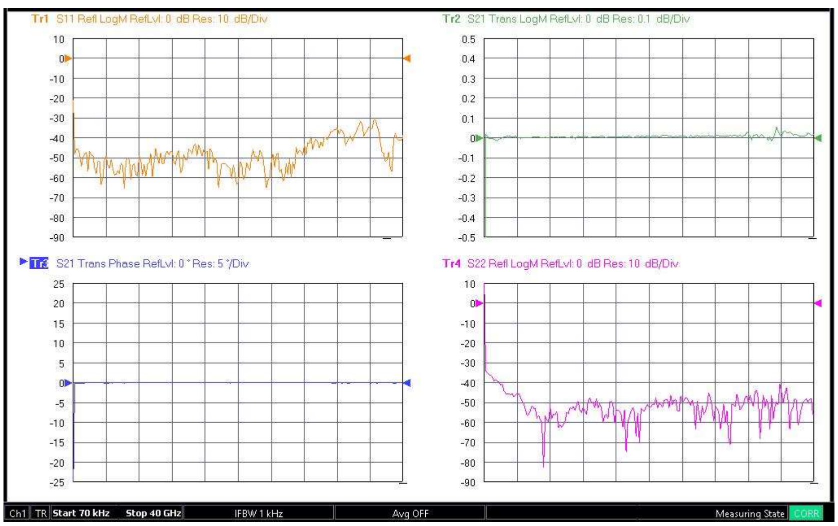

Figure 3: Thru Verification of Differential Calibration

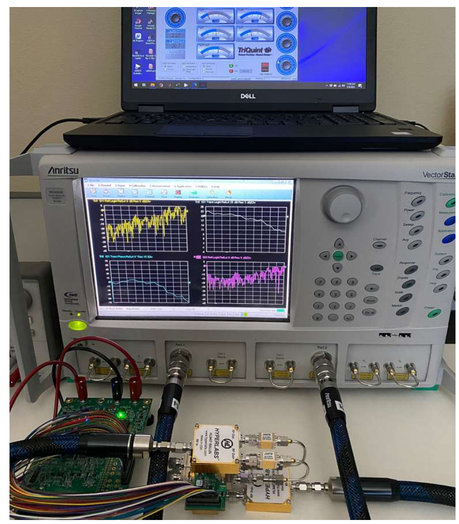

Figure 4: Active 4-port Measurement

4-PORT VNA CALIBRATION AND MEASUREMENT SYSTEM

A block diagram of the 4-port measurement system is shown in *Figure 6*. The VNA is Anritsu MS4647B with MN4697C Multi-Port Test Set. Calibrations were performed using Anritsu 36585V-2F Precision AutoCal.

After completing AutoCal, a Thru Update was performed for all port combinations shown in *Figure 6* using Anritsu 33VFVF50C female-female adapter (23.62mm). The delay of the 23.62mm adapter was entered as a calibration coefficient and corrected by the Thru Update operation. However, the slight attenuation of the adapter was not corrected. As a result, insertion gain measurements taken on the 4-port VNA measurement system are slightly optimistic.

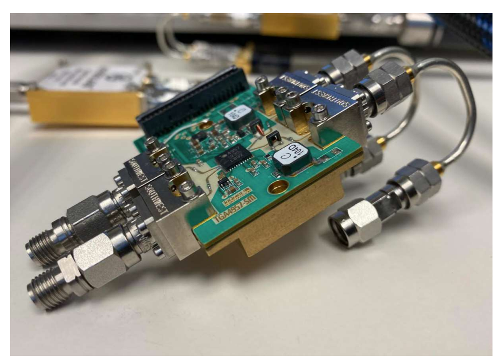

Figure 5: Defined DUT

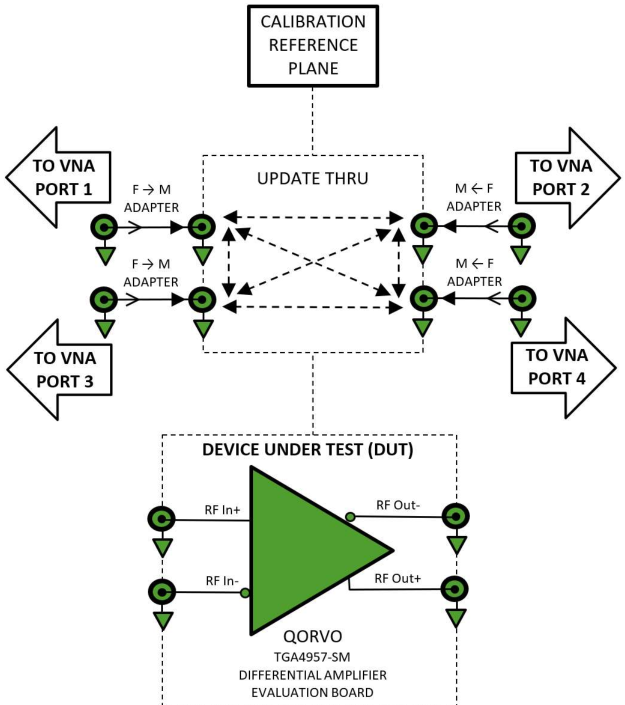

Figure 6: Block Diagram of 4-Port VNA Measurement System

S-PARAMETER TEST RESULTS

Measurements obtained from both test systems are compared in *Figure 7* below. The red traces represent data collected on the 4-port VNA measurement system, and the blue traces represent data collected on the 2-port VNA system using HL9407 baluns.

The return loss data from the 2-port system is noisy and was smoothed with a 4.5% moving average in the plots at right. The raw data is presented in *Figure 8* on the following page. Port 1 return loss data is noisier than Port 2, which may be related to the semi-rigid cables that were integrated into Port 1 of the calibrated measurement system. The cables may have deformed due to torquing and flexing after calibration.

The S21 gain response measured with the 4-port measurements system is notably higher than S21 measured on the 2-port measurement system. This can be attributed to two factors. First, the 4-port

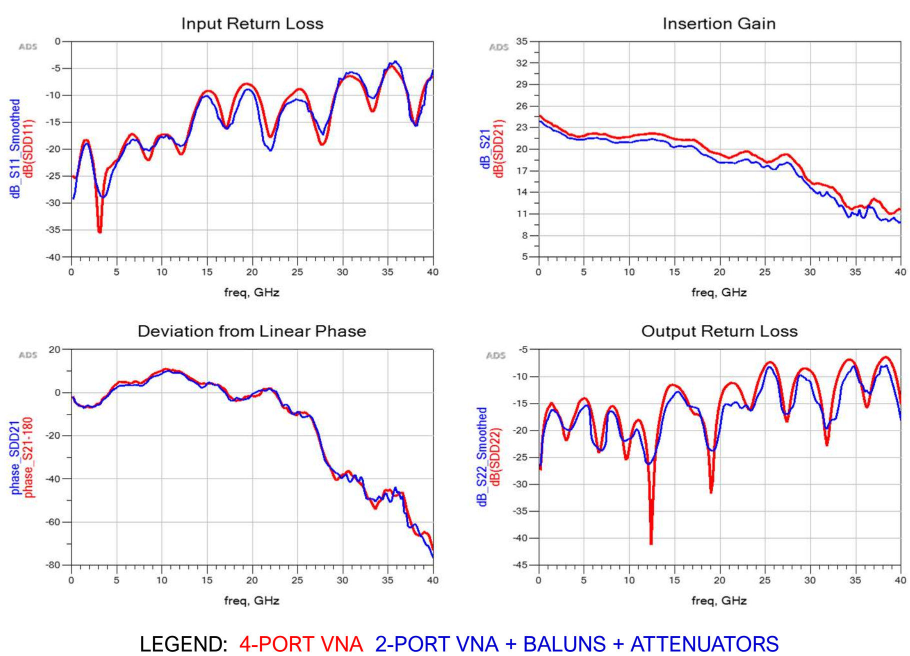

Figure 7: Measured Differential S-Parameters

measurement system was used to characterize a DUT that did not include any coaxial adapters nor cables. In contrast, the 2-port measurements system was used to characterize a DUT that included adapters and cables. Second and mentioned previously, the Thru Update used during calibration of the 4-port measurement system did not account for insertion loss of the Anritsu 33VFVF50C female-female adapter. These two factors explain the discrepancy in measured S21 response.

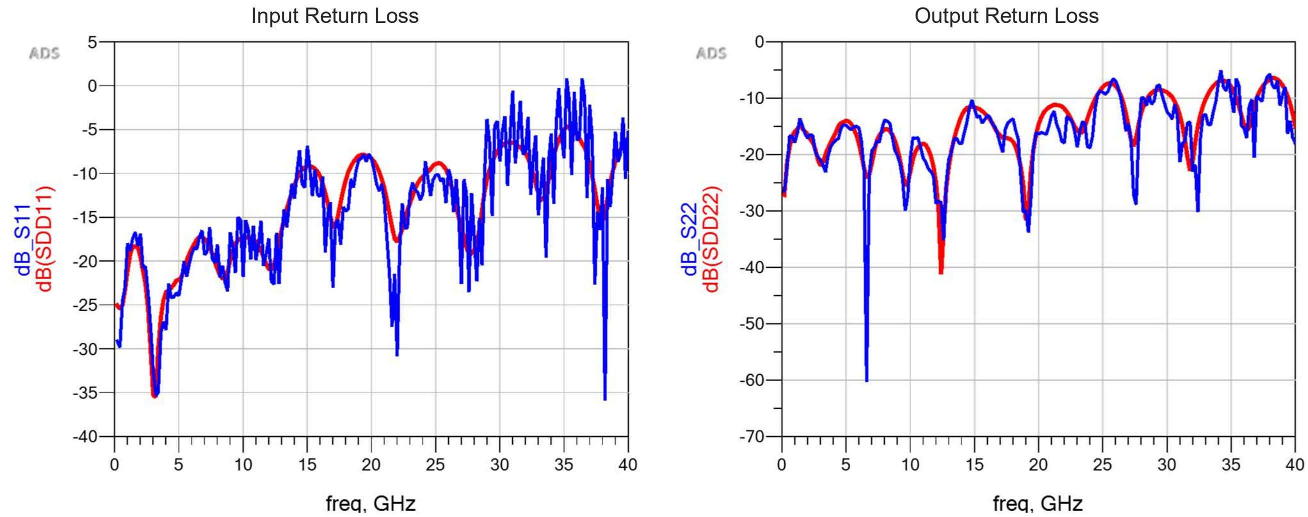

Figure 8: Comparison of Raw Return Loss Data

CONCLUSION

This application note demonstrates accurate differential s-parameter measurements obtained from a single-ended 2-port VNA using HYPERLABS' HL9407 broadband baluns and HYPERLABS' HL9427-10 10dB attenuators. This measurement system is a cost-effective alternative to purchasing a multi-port test set for a VNA. It is worthy of note, that the differential s-parameters reported in this application note are only a subset of the full mixed mode s-parameters that were obtained from the 4-port measurement system. The 4-port measurements system yields common mode and mode conversion s-parameters in addition to differential s-parameters.

[1] James R. Andrews, "Differential VNA Measurements Using Single-Ended, Two Port Instruments and BALUNs", Picosecond Pulse Labs Application Note, AN-21, Dec. 2008