Three port device S-parameter characterization by means of an original three port test set

THREE-PORT DEVICE S-PARAMETER CHARACTERIZATION BY MEANS OF AN ORIGINAL THREE-PORT TEST SET

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ABSTRACT

A three-port network analyzer, implemented using commercial available hardware is presented. Test set calibration is accomplished through a particular calibration procedure which requires only conventional standards, used for two-port applications, and minimizes the number of their connections.

Experimental verification was carried out through measurement of a directional coupler and several devices with one and two ports.

1. INTRODUCTION

Three port network analyzers are up date not commercially available, so that to measure 3-port devices several alternative approaches, based on conventional two-port measurement systems were proposed.

Those techniques require three full two-port measurements to obtain the 3-port device parameters. During these two-port measurements the third device port should be terminated with perfectly matched load. Since this requirement cannot be met in practice with sufficient accuracy, mismatch errors are induced.

An exact solution was proposed [1] in order to solve this practical problem, based on a S-parameter normalization and renormalization by means of matrix transformations, to various sets of port impedances.

A computer iterative solution was presented in [2] by assuming the knowledge of the imperfect termination. Another recent approach [3] tries to overcome the mismatch problem by using time domain techniques.

In this paper a realization of a 3-port S-parameter test system, implemented with ordinary commercial instrumentation is presented. Three measurement ports are really implemented and the measurements are carried out without any device switching on a two-port system.

The calibration follows the more general one introduced by the authors in [4]. This new procedure requires only conventional standards, used for two-port applications, and minimizes the number of their connections.

Experimental results were carried out through measurements of one, two and three port devices connected to the test set ports in several different ways. Good agreement of the same corrected S parameter measured at different test set ports was observed.

2. TEST SET DESCRIPTION

The system block diagram, shown in figure 1, consists of a vector network analyzer, a pair of four channel frequency converters, microwave switches and directional couplers.

In order to allow ratioed measurements between voltage waves sampled by two different frequency converters, one channel in each frequency converter is used as a reference channel for NWA phase locking. An IF switch built into one of the two test sets provides the proper signals to the IF converter for the further down-conversion and digital signal processing.

Obviously a more complex n-port test set could be assembled by combining several blocks like the one here described.

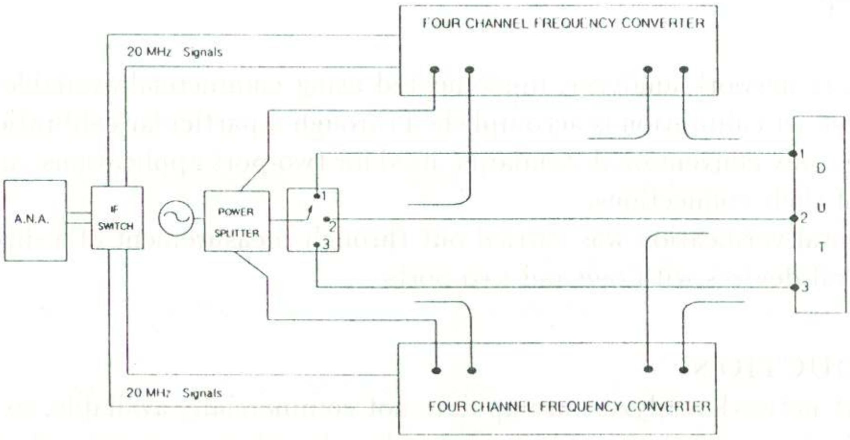

Figure 1: Block diagram of the 3-port implemented S-parameter test set.

3. CALIBRATION TECHNIQUE

The mathematical approach of the calibration technique for the more general n-port case is completely described in [4]. A particular switch error correction is performed and allows to use the extention of two port error box models presented in figure 2 to the case of three-port.

The used matrix solution allows to carry out the whole calibration by means of a simple algorithm here summarized (see figure 3):

1. an usual one-port calibration is performed at port 1 by using three known standards; in these measurements, since the other measurement ports of the network analyzer are not involved the termination of the other two-ports does not play any role and so these ports can be left open;

2. a standard thru line is then connected between ports 1 and 2 and between ports 1 and 3, and full two-port measurements are carried out.

Less standard connections are required to fully calibrate the 3-port test set by this technique respect the SOLT technique [5] used to calibrate a two-port network analyzer.

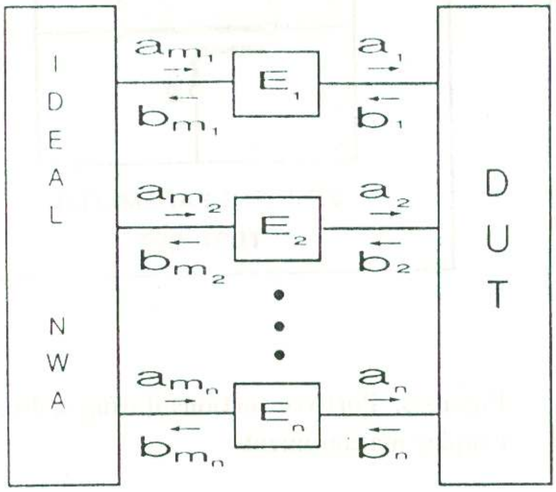

Figure 2: 3-ports test set error box model

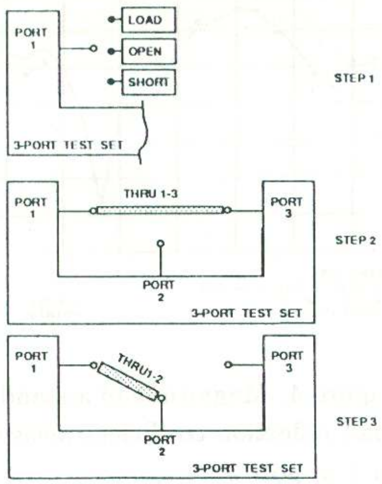

Figure 3: 3-port calibration steps

4. EXPERIMENTAL RESULTS

Several tests were carried out by measuring passive components with one, two and three ports.

A coaxial 3.5 mm sliding load procedure and two offset short standards were used to calibrate port 1 from 3 to 18 GHz. A broadband 50 ohm load was then measured on ports 2 and 3 while the unused ports were left open.

The results reported in figure 4, are in very good agreement, and prove that all the NWA test ports are able to measure well matched loads (-40 dB) with the same accuracy.

The full 3-port scattering matrix of a directional coupler connected as shown in figure 5 was measured. To show the precision of the test system the more significant transmission parameters S_{ij} and S_{ji} were compared each other and their ratios are presented in figure 6, figure 7 and figure 8.

All results agree very well with the expected ones and seem to show an accuracy only slightly worse than usual two-port measuring systems.

ACKNOWLEDGMENTS

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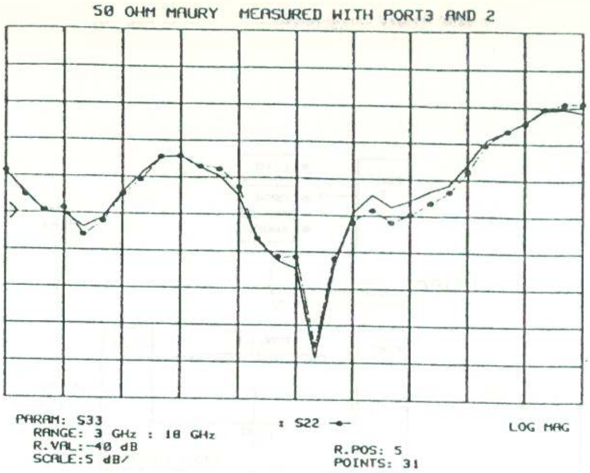

Figure 4: Magnitude of a standard matched load reflection coefficient measured at port 2 and at port 3.

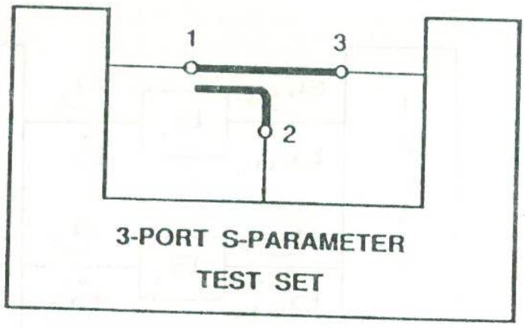

Figure 5: Port connections during a directional coupler measurement

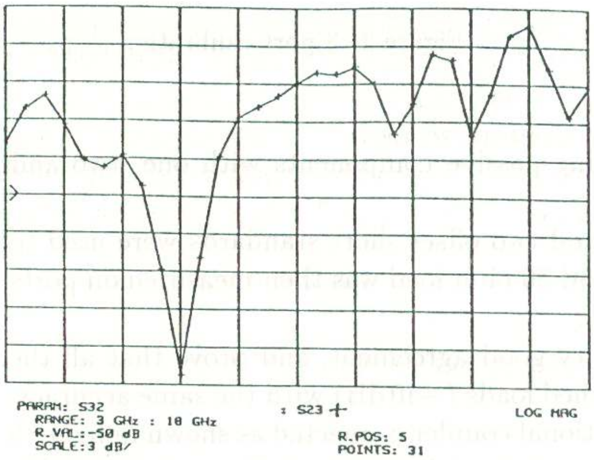

Figure 6: Comparison between S_{32} and S_{23} of a directional coupler

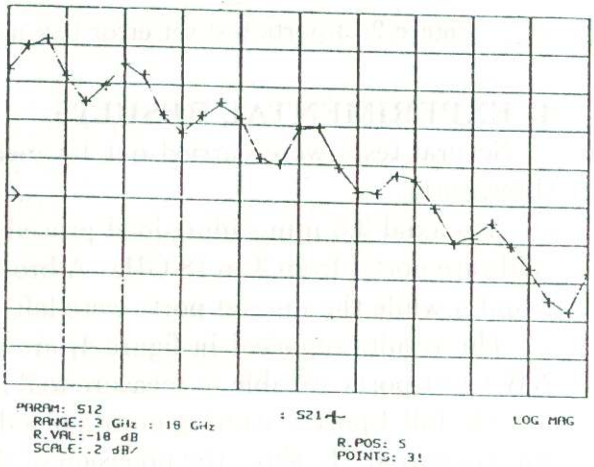

Figure 7: Comparison between S_{12} and S_{21} of a directional coupler

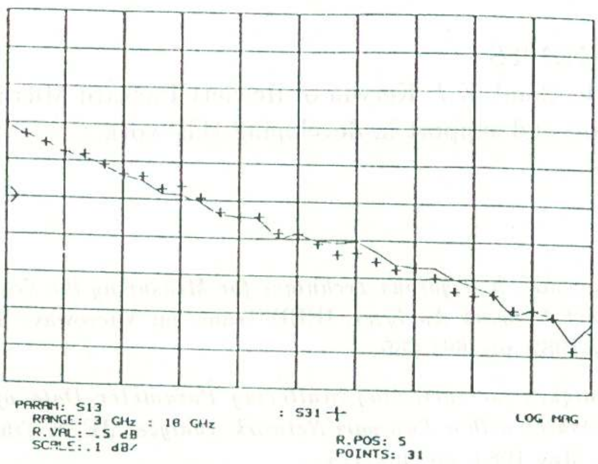

Figure 8: Comparison between S_{13} and S_{31} of a directional coupler