EVALUATION OF A 94 GHz DIODE-BASED DUAL SIX-PORT NETWORK ANALYZER

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ABSTRACT

The feasibility and accuracy of a 94 GHz diode-based dual six-port network analyzer is demonstrated. Consistency experiments show that the systematic errors are acceptably small: the attenuation measurement uncertainty is 0.01 dB at low attenuation increasing to 0.3 dB at high attenuation (40 dB); the reflection coefficient measurement uncertainty is less than 0.008.

INTRODUCTION

The dual six-port technique is an attractive candidate for millimeter wave network analyzers because no down conversion to intermediate frequencies is needed. The problems associated with stringent requirements on mixers and multiple sources are therefore avoided. Since the introduction of the technique over ten years ago, there have been considerable advances in the theory (1)-(3) and hardware (4)-(6) of the dual six-port network analyzer (DSPNA). However, these have all been microwave systems. This paper describes the evaluation of a recently developed diode-based 94 GHz DSPNA for measuring two-port s-parameters.

SYSTEM DESCRIPTION

The DSPNA, shown schematically in Fig. 1, is fully automated except for the manual three-port waveguide switch. The computer controls the phase shifter, the attenuator, and the frequency of the Gunn oscillator during operation, and performs all the required computations. The "thru-reflect-time" calibration technique is used with calibration standards similar to those described in (4).

Central to the system are the two discrete waveguide six-port junctions which are mounted on sliding platforms opposite each other. These junctions are the same units used in the single six-port reflectometer previously described (7). The sliding sections are connected to the fixed feed network via flexible Teflon waveguides, allowing 9 inches of linear translation between the measurement ports of the six-port junctions. A 5 mW Gunn oscillator supplies the power, and 1N53 point contact diodes are used as power detectors. The diodes are calibrated with an

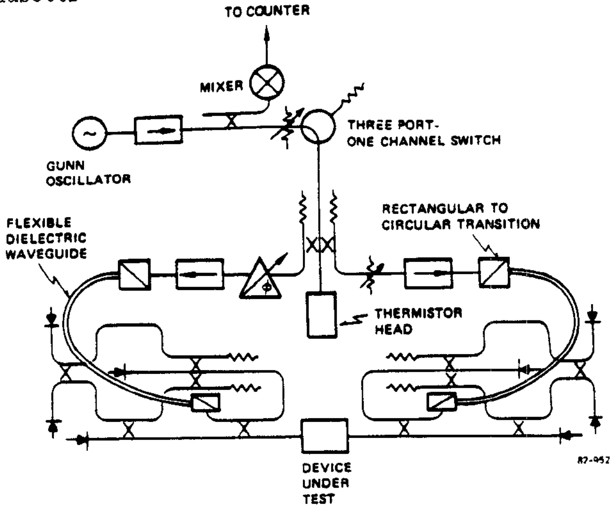

Fig. 1 Dual six-port network analyzer schematic.

automatic, in situ process. Care must be taken to ensure that the calibration range is not exceeded during operation.

SYSTEM PERFORMANCE

The system was evaluated by comparing the results of consistency experiments with the standard deviation in ten repeated measurements. As shown below, they are on the same order indicating that the systematic errors are acceptably small.

A. Attenuation

In this test the s-parameters of two 3 dB, two 10 dB, and two 20 dB attenuators were measured individually. Then varous combinations of two attenuators were measured in cascade. The measured s-parameters of the cascaded pairs were compared with those calculated from the individual s-parameters. These results are summarized in Fig. 2. The open circles are a plot of the standard deviation in ten repeated measurements of attenuation, $|S_{21}|^2$. The solid line is a least-squares fit to this data. It should be pointed out that the standard deviation does not include the connect-disconnect errors since the devices were not removed from the network analyzer during the repeated measurements. The closed squares are the difference between the measured and calculated s-parameters of the cascaded pairs as described above.

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In all cases, the difference is on the same order as the standard deviation indicating that the systematic errors are acceptably small. The error in measuring attenuation is 0.01 dB at low values of attenuation increasing to 0.3 dB at 40 dB.

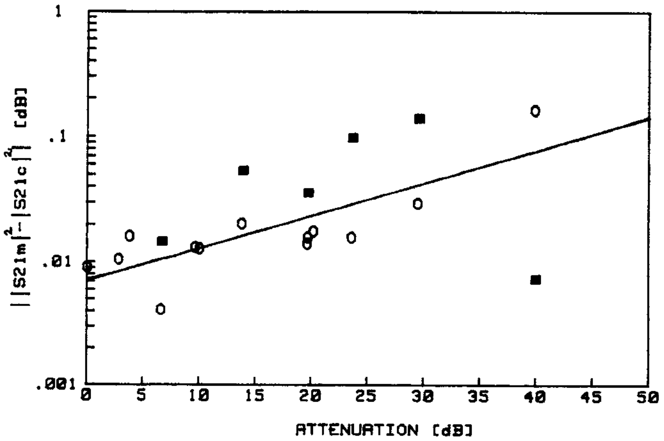

Fig. 2 Comparison of the difference between measured and calculated attenuation (■), and the standard deviation in ten measurements of attenuation (O). The straight line is a least-squares fit to the standard deviation.

B. Reflection Coefficient

Measurements similar to the above were made to evaluate the system performance in measuring reflection coefficient. In this case the attenuators were cascaded with one-ports of nominal reflection coefficients 0.02, 0.06, 0.10, and 1.0. The summary of these measurements is shown in Fig. 3. The open circles are standard deviation in ten measurements of the device under test. As before, this does not include connect-disconnect errors. A separate experiment to evaluate this error contribution showed that it is approximately 0.002. This is shown in Fig. 3 by the dashed line. The closed squares represent the difference between the measured cascaded pairs of attenuator-one-port combination, and that calculated from the measurement of the individual devices. In all cases, the difference is within the order of the standard deviation showing that the systematic error is acceptably small. The error in measuring reflection coefficient is less than 0.008.

CONCLUSIONS

The dual six-port network analyzer provides accurate, affordable measurement of s-parameters in the millimeter wave band, and can solve many measurement problems such as the de-embedding of components. It can be improved by temperature stabilizing the six-port junctions, thus increasing the stability of the calibration constants. Better diode detectors and a phase locked sources will improve the bandwidth and accuracy of the system.

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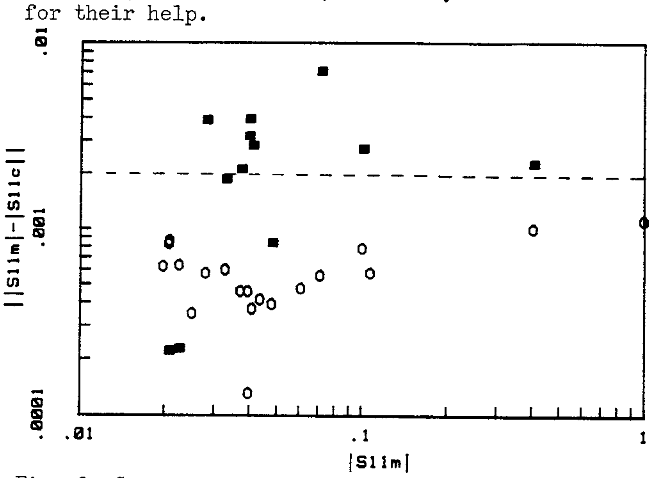

Fig. 3 Comparison of the difference between measured and calculated refleciton coefficient (■), and the standard deviation in ten measurements of reflection coefficient (O). Dashed line shows the connect-disconnect errors.

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