A SIX-PORT AUTOMATIC NETWORK ANALYZER*

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Abstract

This paper describes a programmable calculator-controlled six-port system designed to measure S_{21} and S_{11} over a wide microwave frequency range without disturbing the device under test. Measurements taken from 7 to 12 GHz show that results within 1% can be obtained.

Introduction

The need for wideband, accurate, fast, and inexpensive microwave measurement of S parameters has been growing at a rapid rate. Although the computer-controlled automatic network analyzer satisfies the first three characteristics, it carries a high price tag. Some recent work at the National Bureau of Standards (NBS)[1,2] on programmable calculator-controlled six-port measurement systems has shown promise in reducing the cost of automated measurements without sacrificing accuracy. Expanding on the NBS work, we have built a six-port automated network analyzer (SPANA) designed to measure S_{21} and S_{11} from 2 to 18 GHz with accuracies of the order of 1%[3].

The main feature of the technique is that using a six-port junction with a square law diode detector on each of the four output ports, one can determine the amplitude and phase of the ratio of signals at the two input ports once the calibration constants are known[4]. The simplicity of the microwave detection process reduces the cost of components needed for the usual frequency conversion methods and permits automation via a programmable calculator based system.

System Description

A block diagram of the SPANA is shown in Fig. 1. Some salient features are (1) the entire system is under control of an HP9830A programmable calculator which can also handle all the required computations, (2) all RF components can be used over the entire 2 to 18 GHz frequency range, (3) as in the NBS vector-voltmeter system[1], special components are included for self-calibration in the S_{21} mode, (4) unlike the NBS vector-voltmeter no isolators are included. A photograph of the complete system showing the instrument cabinet and calculator appears in Fig. 2.

Calibration and Measurement Procedure

A self-calibration procedure[5] is employed for measurements. Under calculator control, sets of diode output voltages are acquired and stored with the 2-position insertion device in each state for each of the 6 possible combinations of the 2-position attenuator and 3-position phase shifter. From these readings, the six-port calibration constants for S_{21} mode are determined using an eigenvalue approach. This new software is simpler, faster, and more dependable than previous methods. The six-port reflectometer constants are found using 4 standards at the unknown terminal: a

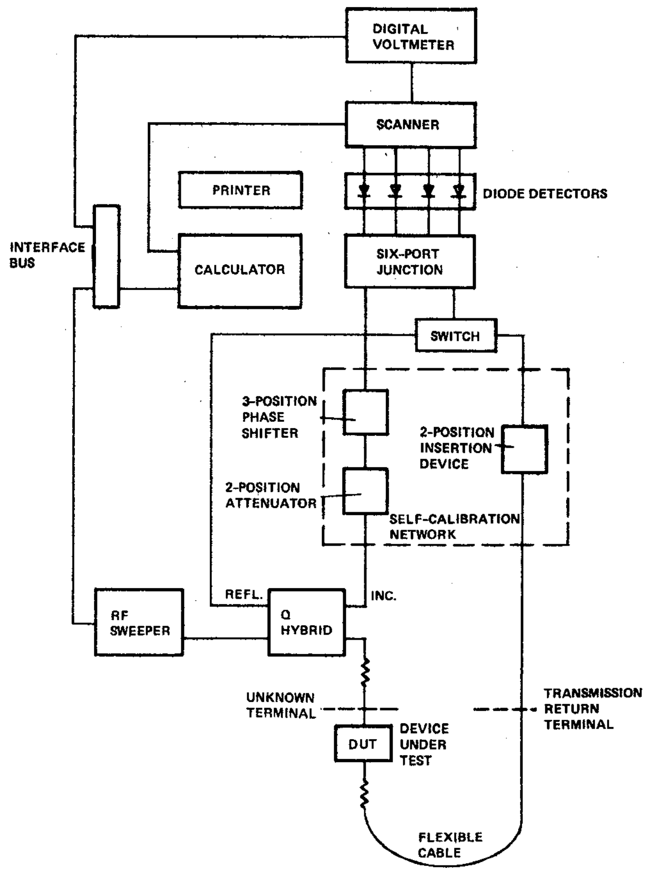

FIG. 1 Six-port automatic network analyzer block diagram.

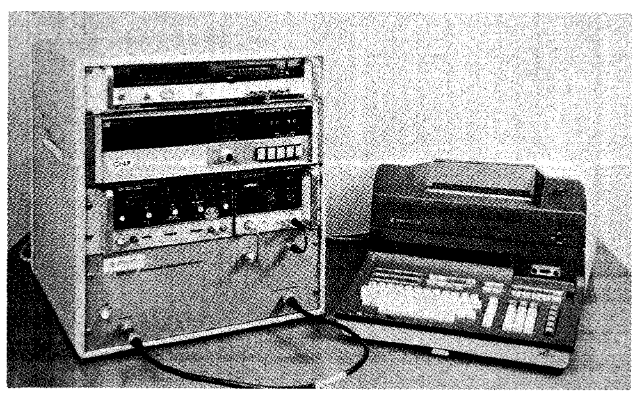

FIG. 2 Sperry six-port automated calibration system.

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matched load, a short, and two offset shorts. Once calibration is complete, the S_{21} of a device under test (DUT) is determined in three steps. First a through measurement without the DUT is performed. Next, the two output terminals are connected to matched loads in order to obtain a correction term for the effect of leakage through the six-port junction. Then the DUT is connected and measurements taken. The three sets of 4 diode voltage measurements are then used with the calibration constants to compute the unknown S_{21}. The S_{11} of the DUT is more readily found by switching internally to the reflectometer mode and acquiring the 4 diode voltages.

Results

The six-port system was used to measure attenuation over the 7 to 12 GHz frequency range. The results of two of the measurement runs on type N coaxial attenuators are illustrated in Fig. 3 with three different sets of data points. One set is the insertion loss values along with bounds for the maximum uncertainty as calibrated by NBS. A second set shows the best six-port data selected from about five runs taken on different days. Here the criterion for best was the data closest to the calibration values. A third set illustrates the scatter for a more typical run. This data demonstrates the good agreement between the best run and the calibrated values. The scatter increased somewhat for 40 dB and was poor at 50 dB.

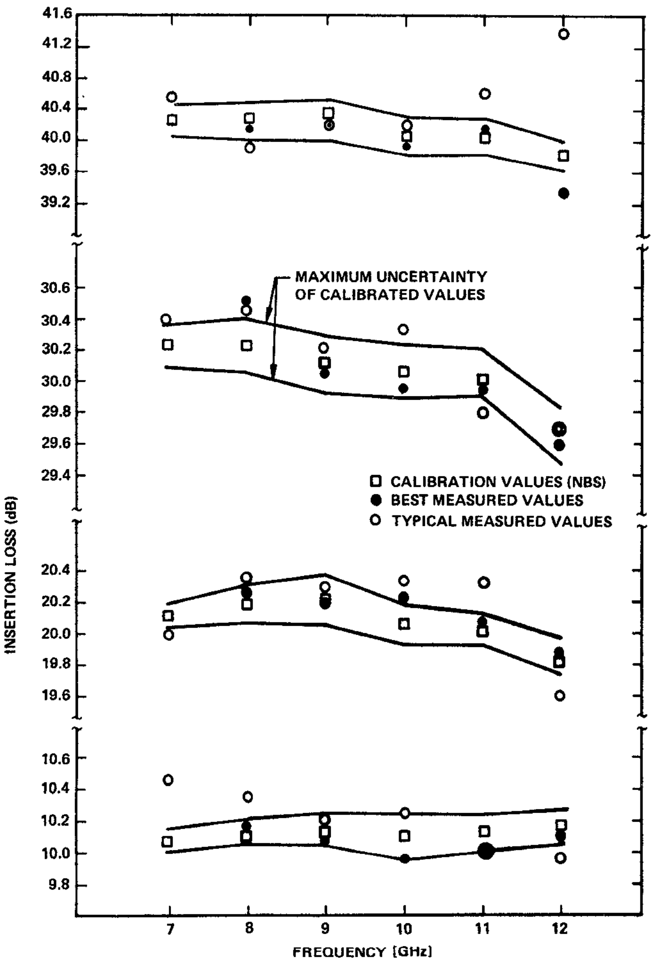

FIG. 3 Six-port insertion loss measurement at 10 dB, 20 dB, 30 dB and 40 dB.

Fig. 4 shows the measured deviation from ideal angles for three offset shorts in the reflectometer mode. Agreement for the shorts offsets is within 1^o and deteriorates to almost 5^o for the longest one.

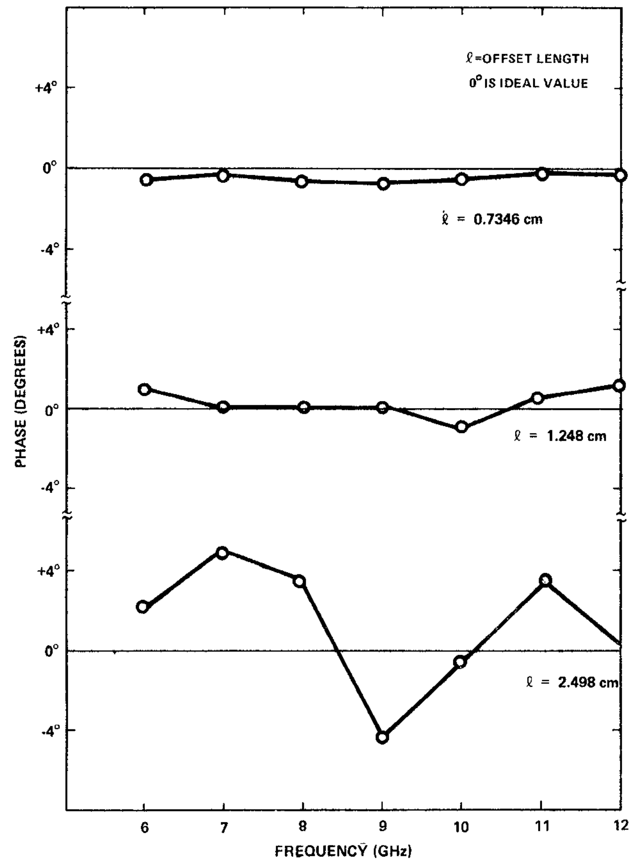

FIG. 4 Deviation from ideal phase values for offset shorts.

A preliminary investigation of error sources indicates that mismatch uncertainty is the largest source of attenuation errors. This could be reduced via a software correction for the errors. However a more promising approach may be to use two six-port junction, one on each side of the DUT, as recently proposed by Hoer[6]. In conclusion, through measurements from 7 to 12 GHz on the calculator-controlled system described above, we have demonstrated that results within 1% can be achieved.

References

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