# A DUAL SIX-PORT AUTOMATIC NETWORK ANALYZER AND ITS PERFORMANCE TESTS*

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## ABSTRACT

A computer controlled six-port ANA (Automatic Network Analyzer) capable of measuring complex reflection coefficients of one-port devices, effective efficiencies of power sensors, and S-parameters of two-port devices over 2 - 18 GHz is described. System calibration, based on the TRL technique is discussed and performance tests on measuring reflection coefficient and S-parameters are summarized.

## INTRODUCTION

Since Hoer and Engen introduced the six-port concept in 1972 a considerable theoretical work has been done, and a number of six-port systems have been implemented and demonstrated good performances (1) - (5).

At the Korea Standards Research Institute, the national standards laboratory recently established in Korea, we have made plans to set up versatile six-port ANA to meet most of the microwave measurement needs.

The first system completed is a dual six-port ANA for the frequency range of 2 - 18 GHz. The system is capable of measuring complex reflection coefficients of one-port devices, effective efficiencies of power sensors (thermistor mounts, thermocouple power sensors, etc.) and S-parameters of two-port devices. In this paper we will describe the hardware configuration and the calibration of the system as well as the results of the performance tests.

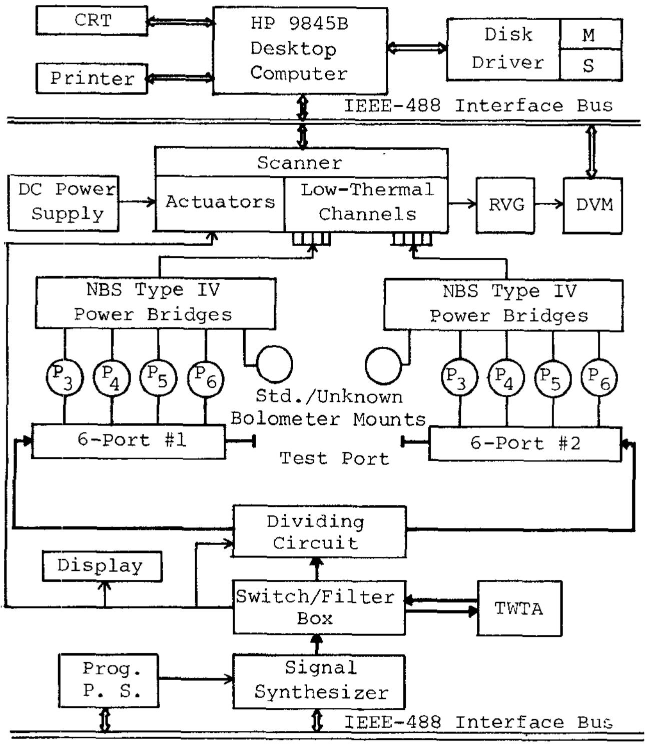


Fig.1. Block diagram of the dual six-port ANA

## SYSTEM DESCRIPTION

The block diagram of the dual six-port ANA is shown in Fig.1. All instruments are under the control of an HP 9845B desktop computer via the IEEE-488 standard interface bus.

The six-port itself is the preferred Engen's configuration(1). The 3.5-mm semi-rigid cable and SMA connectors have been used for the interconnection between components. The RF input port, measurement port, and remaining four ports terminated by thermister mounts are consisted of type-N connectors.

The dividing circuit between the signal source and six-port sensors is used to provide the phase differences of 90$^{\circ}$, 180$^{\circ}$, 270$^{\circ}$, and 0$^{\circ}$ between the RF signals applied to six-port #1 and six-port #2.

The technique used for calibrating the dual six-port ANA is based on the "Thru-Reflect-Line(TRL)" technique. In addition to the three basic steps of the TRL method, we have three more steps, one for power calibration and two for system redundancy and check standard('open' and '10 dB pad'). With all power readings obtained from the above six steps, the six-port to four-port reduction is performed and the TRL solution is obtained at each frequency(2),(3). Three-port calibration constants needed for measuring the S-parameters of non-reciprocal two-port device are also obtained(4).

## PERFORMANCE

An evaluation of the system performance revealed a system malfunction above 17.5 GHz due to two q-points getting closer to each other.

Performances in measuring reflection coefficient and attenuation have been checked over 2 - 17 GHz at 1 GHz step using the similar procedures carried out by Hoer at NBS(5). The results are shown in Fig.2 and Fig.3 at the representative frequencies of 2, 7, 12 and 17 GHz.

Figs.2(a) and (b) show the imprecisions in measuring the magnitude and the phase of reflection coefficients of five terminations of nominal VSWR's

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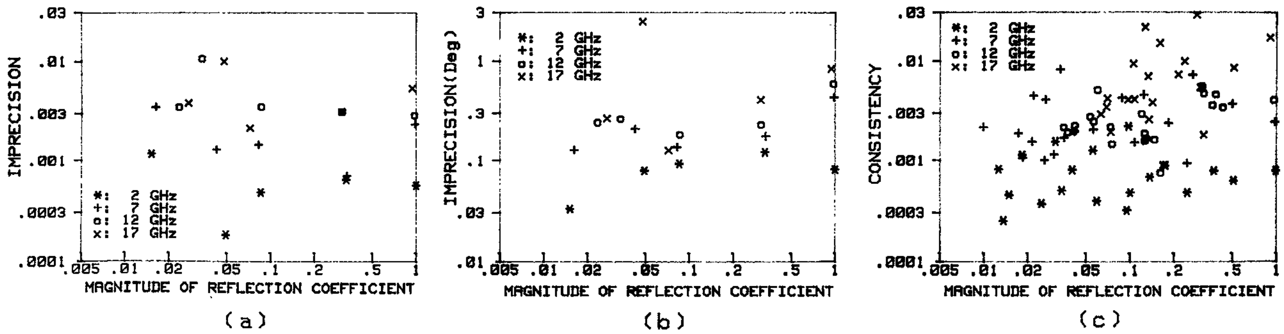


Fig.2. Performances in measuring reflection coefficient. (a) Imprecision in measuring $|\Gamma|$. Standard deviations of five measurements are plotted. (b) Imprecision in measuring the phase of $\Gamma$. $\delta(\phi)$ multiplied by the mean value of $|\Gamma|$ is plotted. (c) Consistency in measuring $|\Gamma|$, see text.

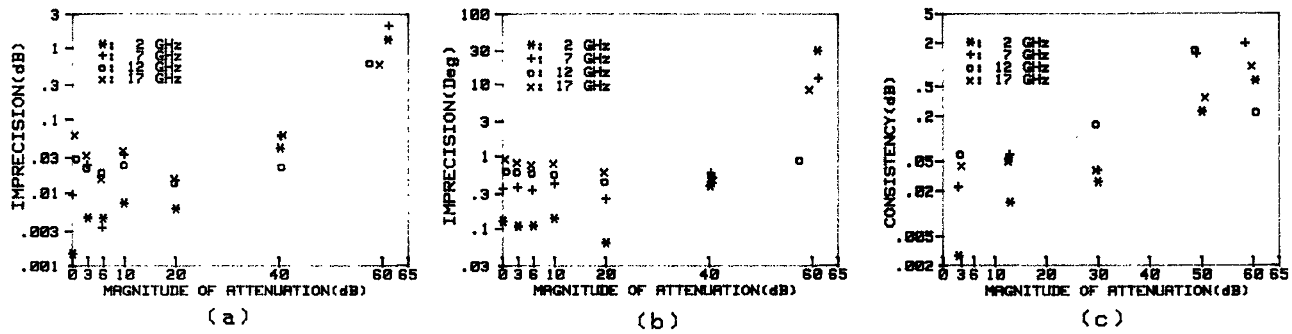


Fig.3. Performance in measuring S-parameters. (a) Imprecision in measuring attenuation. (b) Imprecision in measuring phase shift. (c) Consistency in measuring attenuation.

equal to 1.0, 1.1, 1.2, 2.0, and 'short.' In Fig.2 (c) the consistency represents $||\Gamma_m| - |\Gamma_c||$, where $\Gamma_m$ is the measured reflection coefficient of attenuator/termination combination, and $\Gamma_c$ is the reflection coefficient calculated from the measured S-parameters of the attenuator and the measured reflection coefficient of the termination. There are twenty attenuator/termination combinations out of five terminations of nominal VSWR's equal to 1.0, 1.1, 1.2, 2.0, and 'short' and four attenuators of nominal attenuations equal to 0, 3, 6, and 10 dB.

Figs.3(a) and (b) show the imprecisions in measuring the attenuation and phase shift of seven attenuators of nominal attenuations equal to 0, 3, 6, 10, 20, 40, and 60 dB. In Fig.3(c) the consistency represents the difference of the measured attenuation of two cascaded attenuators and the attenuation calculated from their individually measured S-parameters. There are five combinations of 0 dB + 3 dB, 3 dB + 10 dB, 10 dB + 20 dB, 10 dB + 40 dB, and 20 dB + 40 dB.

As shown, the results are not so good as those obtained at NBS for a single frequency(5). It seems partly due to the connector repeatability of the type-N, which is worse than that of GR-900 or APC-7. We also observed that the output level of TWTA's was not so stable, which might have been partly responsible for the results. It is expected that system performances can be considerably improved by changing the connector type of the measurement port and by leveling the output power or by taking power ratios(i.e. $P_5/P_4$, $P_6/P_4$ etc.) directly with two DVM's, which will eliminate the effect of the power level fluctuation.

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