AN APPLICATION OF THE SIX-PORT REFLECTOMETER TO PRECISION MEASUREMENT OF MICROWAVE ONE-PORT PARAMETERS*

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Abstract

The arbitrary six-port junction concept has been applied to an automated broadband system in the 1-18 GHz frequency range for the measurement of microwave power and reflection coefficient. Performance evaluation results show an improvement in precision over other automated and manually operated measurement systems used at the National Bureau of Standards.

Summary

A broadband measurement system has been developed for determining microwave parameters of one-port devices in the 1-18 GHz frequency range using the six-port junction concept and automation techniques. Although the concept was developed and demonstrated previously,[1] the system described here was implemented as an operational measurement capability for microwave measurement technique development and NBS calibration services. The implementation of this system has demonstrated additional advantages of the six-port junction concept. For example: (1) the six-port junction can be configured with commercial quality broadband microwave components operating over a 1-18 GHz frequency range in a single test set, (2) rf switching is not required in critical subsystems, and (3) a single signal source is used since no intermediate frequency signals are required, thus alleviating the need for phase-locked signal sources.

Figure 1 illustrates the integration of the three major subsystems. These are (1) the cw microwave signal source, traveling-wave-tube amplifiers, frequency programming unit, and rf level programming and control unit, (2) the measurement instrumentation consisting of the six-port junction measurement unit, power meters, voltage scanner, digital voltmeter, and real time clock, and (3) a desk-type programmable calculator used for controlling the measurement system and computation of system calibration parameters and final measurement results. Schematic details of the six-port measurement unit are illustrated in Figure 2.

Techniques were developed for the calibration of the system, the measurement process, and performance evaluation. Particular attention was given to the evaluation of the frequency sensitivity of the six-port junction configuration and power detector thermal drift to determine the criteria for signal sources specification and development of power correction algorithms, respectively.

Calibration of the measurement system is required to determine system constants prior to measurement of the parameters of one-port devices. A thorough summary of the six-port concept and details of system calibration are given in Refs. 2 and 3, respectively. Specifically, the expression for the real net power, P, at the test port reference plane is given by

$$P = \Sigma\, q_i P_i \ , \tag{1}$$

and the reflection coefficient, Γ, at the test port reference plane is given by

$$\Gamma = \frac{\Sigma (c_i + j s_i) P_i}{\Sigma\, \alpha_i P_i} \tag{2}$$

where P_i is the power detected at ports i = 3···6 and the coefficients of P_i are constants determined by the properties of the six-port configuration and associated instrumentation.

The calibration procedure requires a power standard and three or more offset shorts (sliding short) connected to the test port, and the measurement of P_i for each condition. Subsequently, q_i is determined from the solution of a system of equations in the form of equation (1). Calibrating the system to measure Γ requires the observation of P_i for two or more positions of a low reflection termination in addition to the three or more offset short observations mentioned above.

The system is currently used for calibration of bolometer units and power meters at power levels up to 10 mW. The measurement results illustrated in Figure 3 are typical of the system performance for calibration of a coaxial bolometer unit with a type-N connector. The estimated limits of uncertainty show a significant improvement over measurements made on an automated bolometer unit calibration system[4] and manual fixed frequency systems previously used at NBS. The reflection coefficient measurements illustrated have been measured on an independent system since the reflection coefficient measurement capability of this system has not been fully evaluated at this time.

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References

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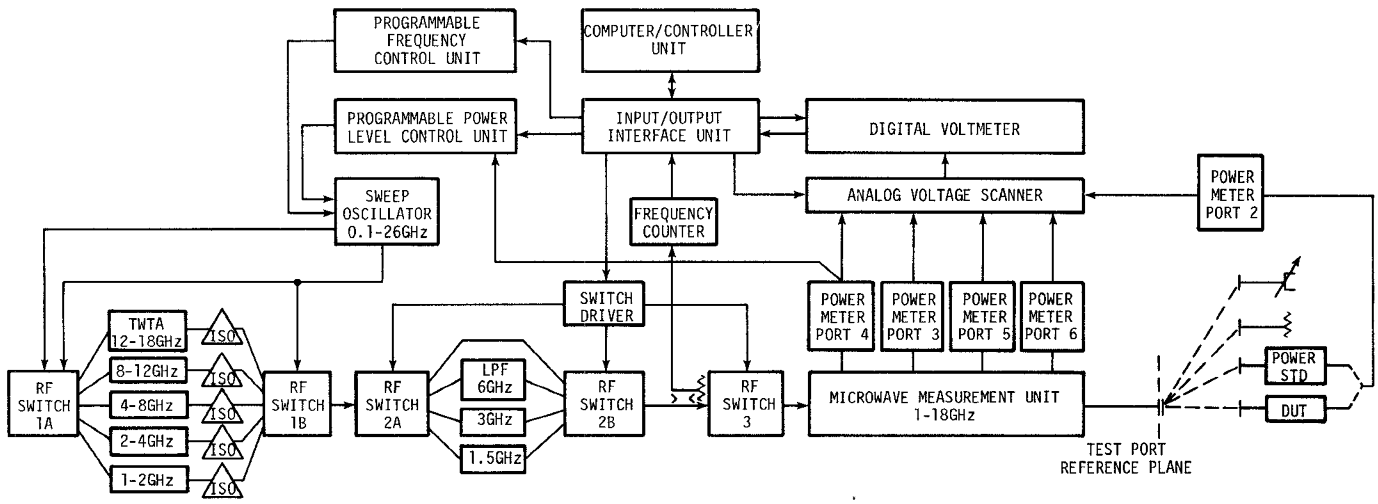

Fig. 1-Block diagram of One-Port Microwave Parameter Measurement System.

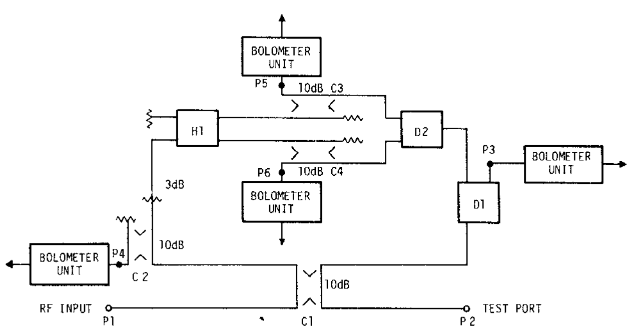

Fig. 2-Diagram of Microwave Measurement Unit (1-18 GHz).

Frequency MHz	Power mW	Refl Coef +-.005	Effective Efficiency	Computed Standard Deviation	Estimated Limits of Uncertainty percent
8000	10	0.000	0.9733	0.0002	1.00
8200	10	0.000	0.9729	0.0001	1.00
8400	10	0.000	0.9724	0.0000	1.00
8600	10	0.000	0.9720	0.0001	1.00
8800	10	0.000	0.9716	0.0002	1.00
9000	10	0.000	0.9712	0.0001	1.00
9200	10	0.000	0.9709	0.0001	1.00
9400	10	0.000	0.9704	0.0003	1.00
9600	10	0.000	0.9702	0.0003	1.00
9800	10	0.000	0.9701	0.0005	1.00
10000	10	0.000	0.9697	0.0006	1.00
10200	10	0.000	0.9694	0.0006	1.00
10400	10	0.000	0.9689	0.0006	1.00
10600	10	0.000	0.9683	0.0005	1.00
10800	10	0.000	0.9680	0.0006	1.00
11000	10	0.000	0.9677	0.0004	1.00
11200	10	0.000	0.9682	0.0004	1.00
11400	10	0.000	0.9677	0.0002	1.00
11600	10	0.000	0.9673	0.0003	1.00
11800	10	0.000	0.9655	0.0005	1.00
12000	10	0.000	0.9628	0.0007	1.00
12200	10	0.000	0.9620	0.0005	1.00
12400	10	0.000	0.9638	0.0004	1.00

Degrees of Freedom for computed Effective Efficiency: 4

Fig. 3-Typical bolometer unit calibration printout.