A SEMI-AUTOMATED SIXPORT FOR MEASURING MILLIMETER WAVE POWER AND COMPLEX REFLECTION COEFFICIENT*

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Abstract

A six-port system has been developed and applied to the precision measurement of power and complex reflection coefficient in WR-15 (50-75 GHz) waveguide. The system is automated except for frequency and switching control for the signal source. This system provides a time saving factor of at least five as compared to a tuned reflectometer with little if any degradation in accuracy.

Introduction

Present state-of-the-art systems for measuring power or reflection coefficients at NBS in the WR-15 waveguide size consist of tuned three- or four-port reflectometers. The tuned system does not lend itself to broadband, stepped frequency measurements. The six-port system described in this paper does lend itself very well to stepped frequency measurements and was chosen for this reason. The system has only been evaluated at six frequencies in the range 55 to 65 GHz, but the extension of its use to broadband measurements should be straightforward. As it presently exists, it still provides a time saving factor of at least 5 to 1 over tuned reflectometers. The measurement uncertainties of the six-port system are equivalent to those obtained using a tuned reflectometer with the possible exception of a slight reduction in the accuracy of reflection coefficient magnitude for small reflection terminations ($|\Gamma| < .01$).

System Design

The six-port system illustrated in Figure 1 was chosen as the basis for the measurement system. The basic theory for this configuration has been described by Engen.[1] All detectors, shown as P_3 to P_6, are thermistor mounts. This configuration makes maximum use of the power available from the signal source; i.e., there is a minimum of power absorbed by terminations other than the four thermistor mounts, and the coupling values shown equalize the available power among the thermistors on arms 3 to 6 and also at the test port. Terminating type power meters or passive terminations are connected to the test port, and the six-port, when calibrated, is used to measure such parameters as effective efficiency and reflection coefficient for these devices.

The system in Figure 1 differs slightly from that described in the reference, and the reason for this change is that there are no commercially available two-way, equal-phase power splitters available in the WR-15 waveguide size. The three-way power divider provides another port at which the P_4 detector can be attached. This is the configuration for the system evaluation given in this paper.

Also shown in Figure 1 is another optional P_4 detector location on the side arm of a conventional three-port directional coupler connected at the test port. With the P_4 detector in this position, the thermistor-coupler combination can be measured as a feed-through type power meter and then removed from the six-port system and used independently. With this optional configuration, the six-port, including the thermistor-coupler combination, measures the equivalent generator reflection coefficient and the available power at the output port of the thermistor-coupler combination.

Detector P_4, in any of the three locations in Figure 1, couples primarily to the incident wave at the test port. Thus, it is used as the detector for leveling the signal source. Thermistor mounts P_3, P_5, and P_6 couple to both incident and reflected waves at the test port. Coupling is closer to the incident wave (approximately 3 dB) than to the reflected wave for reasons of simplification in the solution of six-port equations.

The configuration in Figure 1 also provides a certain phase relationship between the detectors P_3, P_5, and P_6. Ideally, detectors P_5 and P_6 would be in quadrature with respect to the VSWR at the test port, and P_3 would be 135 degrees from both P_5 and P_6 for this voltage ratio. In the actual system, variations of 30 degrees from the ideal were observed. This did not significantly degrade system performance.

The automatic data acquisition and processing portion of the system is shown in Figure 2 and consists of NBS Type II Power Measuring bridges for all thermistor mounts, a scanner for selecting bridge voltages, a digital voltmeter, and the calculator for reading the bridge voltage information, calculating substituted dc powers and system constants.

Software Design

The software for this system was designed to direct an operator through the calibration and measurement procedure, collect all necessary data, calculate system constants, and perform various error correcting functions. The program is in BASIC and, with all constants defined for one frequency, utilizes almost 8000 words of calculator memory.

The details of the software design are not included in this paper, but a brief description of the calibration procedure is given here. The calibration procedure consists of collecting power meter data for a minimum of five sliding short positions, three sliding load positions, one reflection coefficient standard, and one terminating power standard, all connected to the test port. After the calibration process is completed, measurements can be made on unknown power meters or reflections connected to the test port.

System Evaluation

An evaluation was performed to determine both random and systematic uncertainties in measuring power and reflection coefficient. It was found that there was no significant degradation in measurements compared with a tuned reflectometer.

Using the data taken to date, it is estimated that ± 1.5 percent power measurements can be made with this system. The standard deviation for measuring the effective efficiency of an unknown thermistor mount is estimated to be ± 0.20 percent.

The estimate of standard deviation for reflection coefficient magnitude measurements is ± 0.002 and ± 0.5 to ± 3.0 degrees in phase. The systematic uncertainty for reflection coefficient magnitude or phase measurements made on this system were limited by the reflection standard and precision section used in system calibration rather than the technique. It was found that systematic uncertainties of ± 0.005 are not unreasonable for the system in its present form.

The estimates of standard deviation are based on a series of complete system calibrations. No frequency control was applied to the signal generator other than using a ± 0.1 percent wavemeter to intitally set the frequency. Significant improvements in uncertainties for both power and reflection coefficient measurements are to be expected with more system refinements.

Conclusions and Summary

The six-port system works as well as an established, state-of-the-art technique for measuring power and reflection coefficient in the millimeter wave region. Its advantages are elimination of the need for complex tuning procedure and frequency conversion, and the use of relatively inexpensive, commercially available hardware.

Acknowledgment

The author is grateful to Dr. Glenn F. Engen who provided many suggestions for the hardware system design, and who also did the software design for calculating and correcting the system parameters.

Reference

1. G. Engen, "An Improved Circuit for Implementing the Six-Port Technique of Microwave Measurements," paper presented at 1977 International Microwave Symposium, San Diego, California.

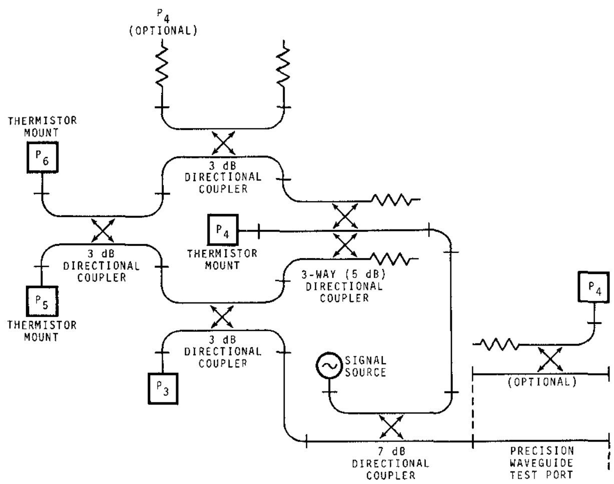

Fig. 1-Six-port waveguide system

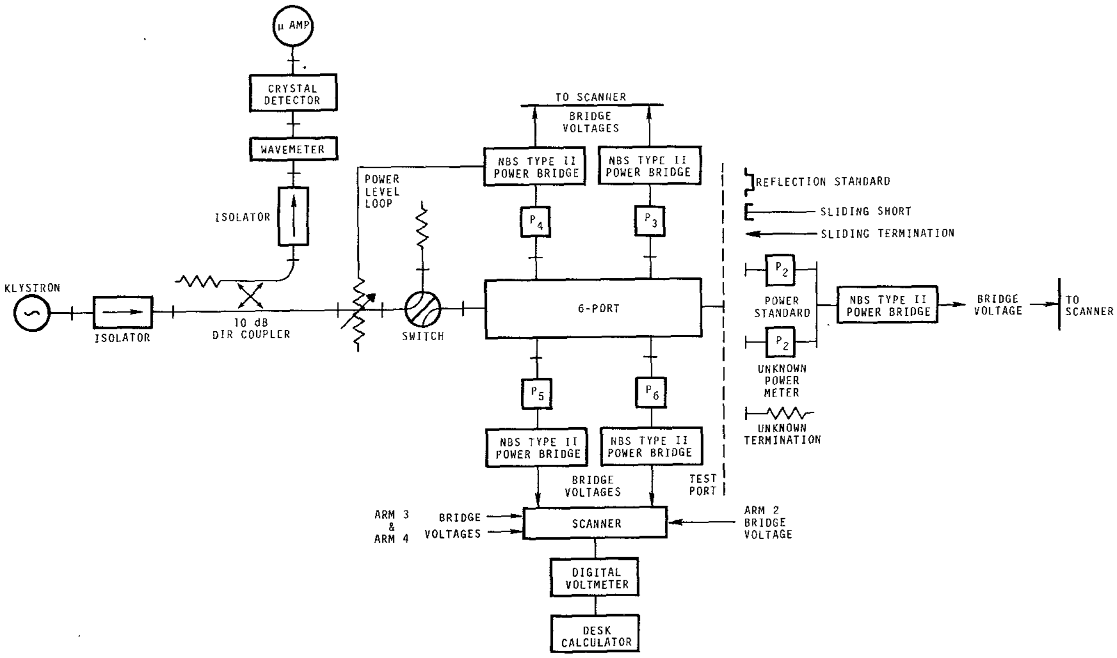

Fig. 2-Block diagram of complete six-port system