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A PROGRAMMABLE LOAD FOR POWER AND NOISE CHARACTERIZATION

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ABSTRACT

A digitally-controlled one-port tuner, providing sixty-four distinct impedances, has been used to examine the relationship between nonlinear power transistor performance and load impedance. In a similar way, the noise parameters of low noise linear transistors have been deduced from measurements using the tuner to control source impedance. All control, measurement and data reduction functions are performed with a desktop computer.

I. Introduction

The characterization of nonlinear power transistors and low noise linear transistors both require measurements to be made under various loading conditions.

Computer control of these measurements is attractive not only from the point of view of data collection and manipulation but also in the equipment control that it provides.

There are two essentially different approaches to the characterization of load-dependent devices; one is to adjust the load until some performance criteria are met, the other is to measure the performance for various known loading conditions and then establish their relationship.

This second method is better-suited to digital control because it requires a finite number of discrete states of the tuner (which can be calibrated) rather than continuous variability.

The desired loading-to-performance relationship can be obtained either by fitting a known equation to the data and solving for the unknown constants or by mapping the parameters using computer interpolation. The first allows for the fact that measurements may be in error, and the equation can be fitted in a least-squares sense to them. The mapping approach assumes the data is exact and performance for other conditions is predicted solely by interpolation. This method is useful when the mathematical relation is not known.

II. Tuner Design

The design requirements of a tuner suitable for both power and noise characterization include:

1. High power handling capability
2. Digital control with good repeatability
3. Adequate range in both amplitude & phase of reflection
4. Low excess noise generation

Notice that no requirement has been placed on the resistive loss of the tuner because, in the applications to be described, a one-port tuner is sufficient. For other measurement methods, this may not be true.

Tuners of the type shown in Figure 1 have been built for different frequency bands. The tuner consists of directional couplers, PIN diodes for control and external loads. For a six diode circuit, as shown, sixty-four distinct impedances are produced corresponding to two states of each diode independently. These are shown in Figure 2 to provide a square grid on the reflection coefficient plane just enclosing the VSWR=3 circle. The tuner is calibrated at a number of frequencies using a conventional network analyzer.

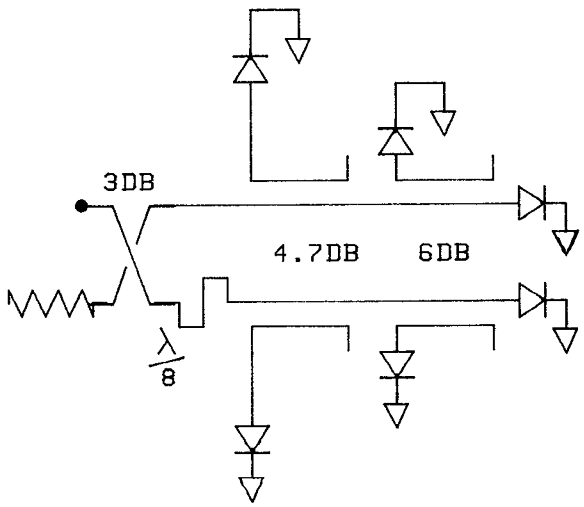

Fig. 1 6-Bit Programmable Load

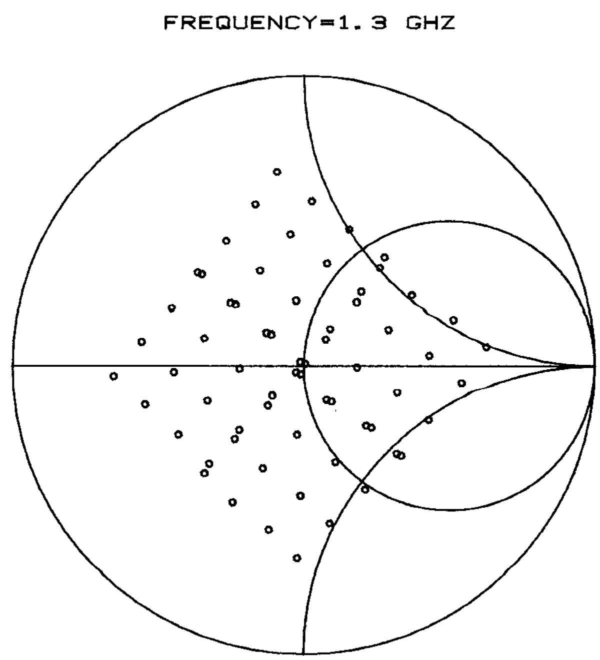

Fig. 2 Programmable Impedances

III. Power Transistor Characterization

Power characterization, as shown in Figure 3, uses a dual directional coupler on each side of the two-port under test, which can be terminated in the programmable load. Two of the coupler outputs can be connected to a "six-port" vector voltmeter system[1] for measurements of both relative amplitude and phase. The six port was chosen to enable measurements to be done with short RF pulses. The dual coupler ahead of the programmable load enables load calibration to be done for each measurement, or use can be made of previously stored data. Typical results of measurements are shown in Figure 4.

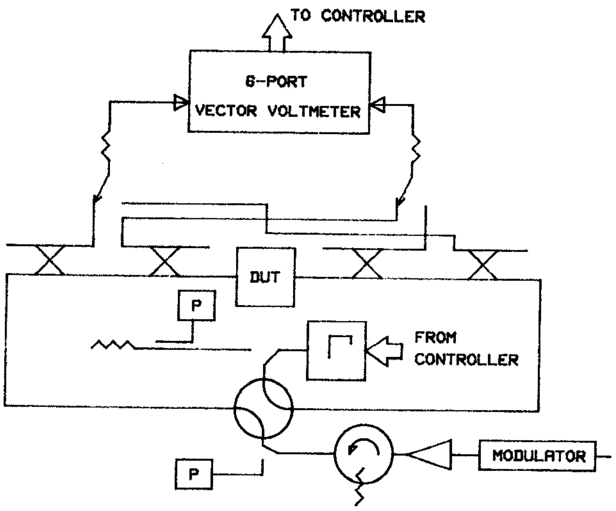

Fig. 3 Pulsed Load-Pull System

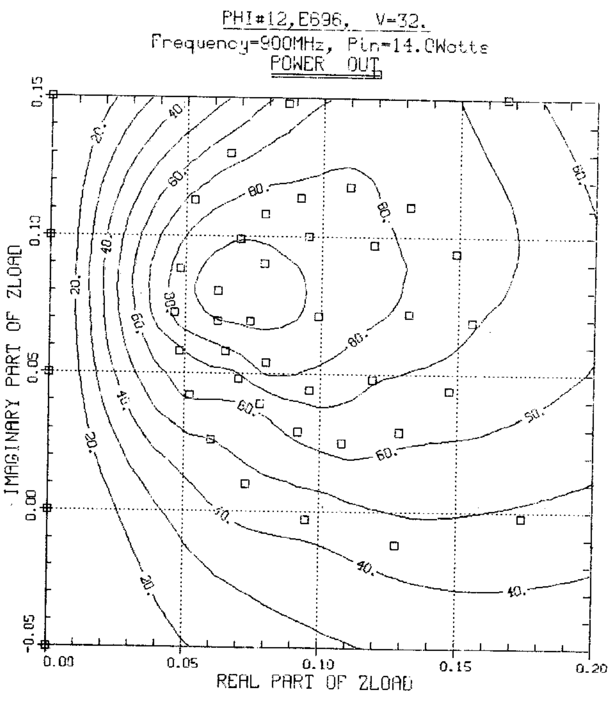

Fig. 4 Interpolated Power Contours

IV. Noise Parameter Measurements

The equation which describes the dependence of noise figure on source admittance contains four independent constants - the noise parameters. In general, determination of the noise parameters requires noise measurements for each of at least four different admittances. More measurements allow smoothing to reduce errors.

It is interesting to compare noise figure measurement procedures that require a two-port tuner, and those for which a one-port is sufficient. In both cases, the number of power measurements necessary to obtain noise figure for each source impedance depends on the availability of other information, such as two-port tuner dissipation loss, tuner and device reflection coefficients.

1. Conventional measurements use a two-port tuner illustrated in Figure 5A. Two power measurements are required for each source impedance, provided the corresponding tuner resistive loss is known.
2. The one port tuner with no knowledge of tuner or device reflection coefficients is shown in Figure 5B. Three power measurements are required; two if either the tuner or the device reflection coefficient is known.

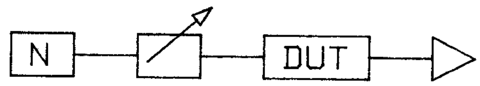

Fig. 5A Two-Port Tuner

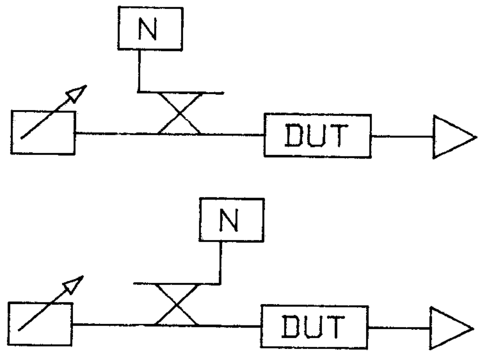

Fig. 5B One-Port Tuner

If both device and tuner reflection coefficients are known, Adamian and Uhlir have shown[2] that one power measurement is sufficient for each source impedance once a conventional noise figure measurement has been taken with, say, a matched source.

Noise Parameters from Overall Noise Measurements.

The Friis equation expresses the overall noise figure of a cascade in terms of the component noise figures and available gains. For the device under test followed by a noisy receiver,

$$F = F_1 + \frac{F_2 - 1}{G_1} .$$

Sannino[3] proposed a method of obtaining G_1 by making overall measurements for two known values of F_2, leaving F_1 constant. As the source impedance for F_1 is varied, not only will F_1 change but also F_2 unless the first stage is unilaterial. A method for obtaining F_2 for unknown source impedances has been proposed by Sawayama[4], which is similar to the one-port tuner method shown in Figure 5, when the receiver input impedance is known. It involves one more power measurement.

In a measurement system using a computer to collect power meter readings under various conditions, it is advantageous to minimize the number of values that are necessary to arrive at the noise parameters of the device under test, remembering that a noise figure measurement requires two.

The procedures described in References 3 and 4 require additional noise figure measurements to allow for changes in the second stage noise figure with input tuning and also to obtain the first stage available gain without resorting to output tuning.

The process can be simplified somewhat by introducing only one additional power measurement for each tuner setting to determine the reflection coefficient magnitude of the first stage output. One can then calculate the second stage noise figure for each tuning condition (knowing its value for a matched source), and also calculate the first stage available gain from its insertion gain (which is already known). Changing the second stage noise figure is unnecessary.

The complete set-up is shown in Figure 6, which assumes that the source tuner reflection coefficient is known. Of course, if the DUT S-parameters are known, the measurement is simplified still further.

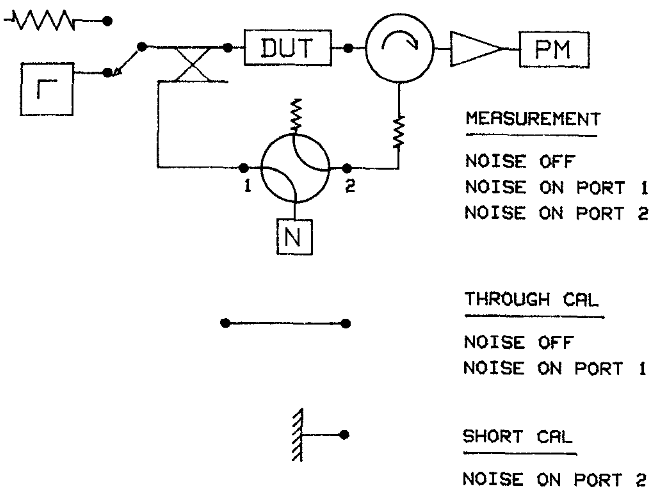

Fig. 6 Proposed Noise Characterization System

V. Discussion

The diode-controlled network is useful for both power and low noise transistor characterization. The same network used as a two-port results in a set of programmable transmission coefficients with the same pattern as its reflection coefficient. One application for this is a calibration transfer standard for network analyzers.

VI. References

(1) Hoer, C.A., "A High Power Dual Six-Port Automatic Network analyzer Used in Determining Biological Effects of RF and Microwave Radiation". IEEE Trans. Microwave Theory Tech. Vol. MTT-29, No. 12, pp 1356-1363, Dec. 1981.

(2) Adamian & Uhlir, "A Novel Procedure for Receiver Noise Characterization". IEEE Trans. on Inst. and Measurement, IM-22, No. 2, pp 181-182, June 1973.

(3) Sannino, "Simultaneous Determination of Device Noise and Gain Parameters Through Noise Measurements Only". IEEE Proc., Vol. 68, No. 10, pp 1343-1345, Oct. 1980.

(4) Sawayama & Mishima, "Evaluation Method of Device Noise Figure and Gain Through Noise Measurements". IEEE Proc., Vol. 69, No. 12, pp 1578-1579, Dec. 1981.