Automated Test-Set for Accurate Measurements of Minimum Noise Figure of GaAs FETs

by

G. Garbo, G. Martines and M. Sannino

Abstract

A new automated method for the determination of input-termination optimum-condition of low noise microwave GaAs FETs is presented.

Since the method is fully automated strong reduction of time-consumption is guaranteed; in addition the method is also accurate because all the effects which influences the noise figure measurements are taken into account.

It is opinion of the Authors that both the test-set and the relevant software are unique.

1. Introduction

It is known to the experimenters in the field of noise figure measurements that some automated microwave tuners are now commercially available, either step motor mechanical tuners or solid state tuners; by consequence it is at last possible to realize fully computer-controlled noise figure measuring set-up.

A new automated test-set for the complete characterization of low-noise devices in terms of noise, gain and scattering parameters through noise figure measurements only will be presented at the next MIOP'90 Conference [1].

However that measuring method had already been presented in the quasi-automated version, i.e. equipped with the manual tuner, in the previuos edition of the same Conference [2].

In that paper the theory of the measurement and all the experimental steps are described; all the advantages by comparison with the conventional ones are pointed out. Further a computer-controlled version of the set-up is described in which the computer carries-out all the measuring phases, i.e. performs the preliminary set of measurements of the calibration run, selects the most convenient operating and measuring conditions for accuracy, controls all the instruments, collects, stores and processes the data, analizes the accuracy, provides the results in form of print and/or diagram.

For this reason, to save space here, as far as the theory of the method is concerned refer to [1,2] and references reported in them.

In this communication we present the application of the automated method to measure directly only the three optimum noise parameter of a GaAs FET, a testing procedure often used in industry.

The Authors are with the Dipartimento di Ingegneria Elettrica, Universita di Palermo, I-90128, Palermo, Italy.

According to the opinion of the Authors, this is the unique set-up which can perform correctly the determination of the optimum noise parameter tern through the direct measuring procedure;the accuracyis higher in comparison with the one of the methods at present known.

Obviously by using the set-up following the procedure for the determination of all the four noise parameters (i.e. simply by selecting the proper menu among the ones offered by the main program) a better accuracy is assured , especially when in the neighbourhood of the optimum noise condition the variations of the noise figure are low.

By other hand the direct procedure has both the advantages of a) higher work speed of the set-up and b) lower number of data to collect and process; for this the method could also be useful for 100 percent testing of devices in industry.

2. The automated test-set

The simplified block diagram of the noise figure measuring set-up is shown in Fig. 1.

The measured noise figure $F_m(\Gamma_{ns})$ is given by

$$(1) \qquad F_m(\Gamma_{ns}) = \alpha_{\Gamma s}(\Gamma_{ns}) \left[F(\Gamma_s) + \frac{F_r(S_{22}') - 1}{G_a(\Gamma_s)} \right]$$

where

- $\alpha_{\Gamma s}$ represents the losses (noise) of the tuner;
- $F(\Gamma_s)$ and $G_a(\Gamma_s)$ are the noise figure and the available power gain of the transistor under test (TUT);
- $F_r(S_{22}')$ is the noise figure of the receiver.

As we can note, a second tuner connected to the TUT output, as in conventional methods, is not used; the TUT is terminated on the low impedance (50 ohm, nominal) of the (input-isolated) receiver.

This offers two main advantages:

a) the rise of oscillations is avoided;

b) to take into account the noise contribution of the "second-stage" (receiver) results more simply (and correct); $F_r(S_{22}')$ is computed from S_{22}' and $F_r(\Gamma_{ns})$; this computation is straightforward if the receiver is equipped with an isolator at the input;

c) automated searching of the optimum input condition for noise is strongly simplified; in realizing the input reflection coefficient Γ_s one tuner only must be driven.

Further it is noteworthy that in the conventional methods the available power gain $G_a(\Gamma_s)$ and the losses $\alpha_{\Gamma s}$) are computed from the scattering parameters measured separately through a network analyzer. This means that correct (automated) determination of the optimum noise conditions is impossible through this way.

On the contrary, following our method all the measurements are carried-out on-line by means of the noise figure set-up only.

In other words, every time the computer drives the tuner in order to realize one of the selected values of Γ_s the parameters $\alpha_{\Gamma s}$, $G_a(\Gamma_s)$ and S_{22} are measured; since $F_r(\Gamma_{ns})$ is known from the calibration run, $F(\Gamma_s)$ is computed from (1) [1,2].

The block diagram of the computer controlled set-up (via HP-IB) is shown in Fig. 2.

3. Computer driving of the tuner

The tuner with which the measuring system is equipped is a step motor mechanical one (Automatic Tuner System - ATS - mod MT 980 A by Maury Microwave) and is driven by its controller in terms of motor step number.

In order to control the tuner by computer directly in terms of Γ_s, a further subroutine has been introduced in the main program, whose algorithm is based on a proper modelling of the tuner. The first part of the subroutine performs the calibration of the tuner through 10/15 measured values of Γ_s properly chosen; these few values are sufficient to obtain any value of Γ_s on the Smith chart with an accuracy of ±3 deg for the phase and ±5% for the modulus in the frequency range 8-12 GHz.

Obviously improvement of accuracy can be obtained by processing more values of Γ_s in the calibration run.

However, this accuracy is not very important because after that the optimum value Γ_o of Γ_s is found it is measured by the reflectometer.

A first approximation modelling of the tuner in terms of lossless transmission lines is shown in Fig. 5, together with a sketched representation of the tuner. On the basis of the modelling a relationship which connects Γ_s to vertical and orizontal positions of the tuner has been derived [1].

In order to show the goodness of the algorithm which compute Γ_s as function of the tuner positions, as an example, computed and measured values of Γ_s at 8 GHz are reported in Fig. 3. Example of the tuner losses at the same frequency are shown in Fig. 4.

4. Experimental verifications

The first experiment of the method for the direct determination of the noise optimum parameter tern have been carried-out on a transistor furnished by TELETTRA for two bias conditions (15% and 50% of I_{DSS}) at 8 GHz. In Table I are reported for comparison i) the optimum tern as computed by the algorithm, ii) the optimum tern as measured and iii) all the four noise parameters previously measured (about two months ago).

TABLE I
Optimum noise parameters tern as computed and as measured together with the four noise parameters of a transistor TELETTRA at 8 GHz and two bias conditions (15% and 50% I_{DSS}).

	15% I_{DSS}				50% I_{DSS}			
	F_o	Γ_{on}		N_n	F_o	Γ_{on}		N_n
comp.	1.37	0.57	162°	***	1.89	0.55	-175°	***
meas.	1.34	0.59	162°	***	1.89	0.58	-176°	***
param.	1.10	0.63	180°	0.203	1.95	0.60	-170°	0.258

REFERENCES

[1] G. Garbo, G. Martines, M. Sannino, "Complete Characterization of Low Noise Devices Through Noise Figure Test-Set Controlled by Computer", Proceedings of Microwave and Optronic Conference-MIOP'89, Sindelfingen, Feb. 28-March 2, 1989 and references reported in it.

[2] G. Garbo, G. Martines, M. Sannino, "A New Automated Test-Set for the Characterization of Low Noise Devices in Terms of Noise, Gain and Scattering Parameters", Proceedings of Microwave and Optronic Conference-MIOP'90, Stuttgart, April 24-26, 1990.

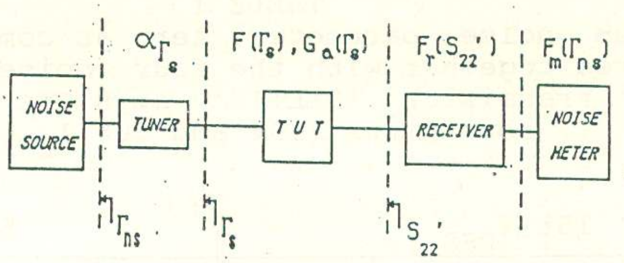


Fig. 1 - Simplified block diagram of the noise figure measuring set-up.

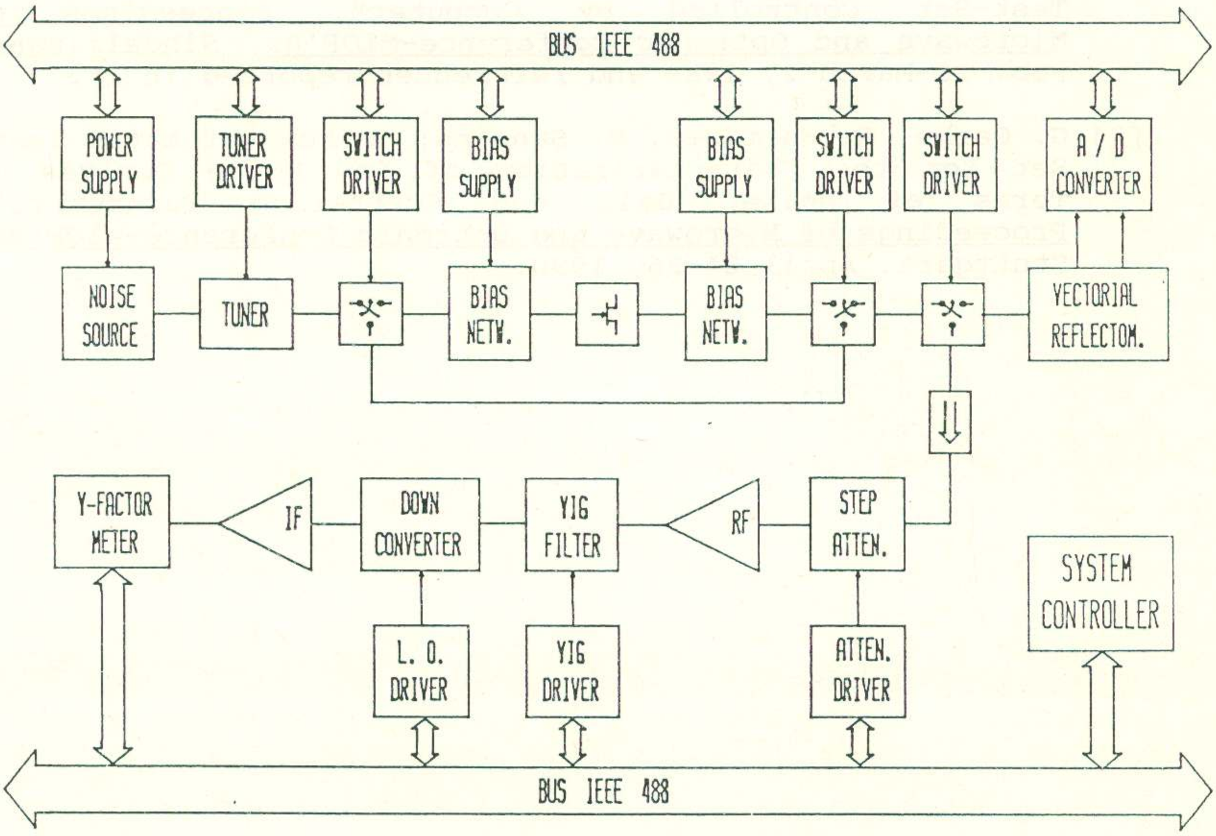
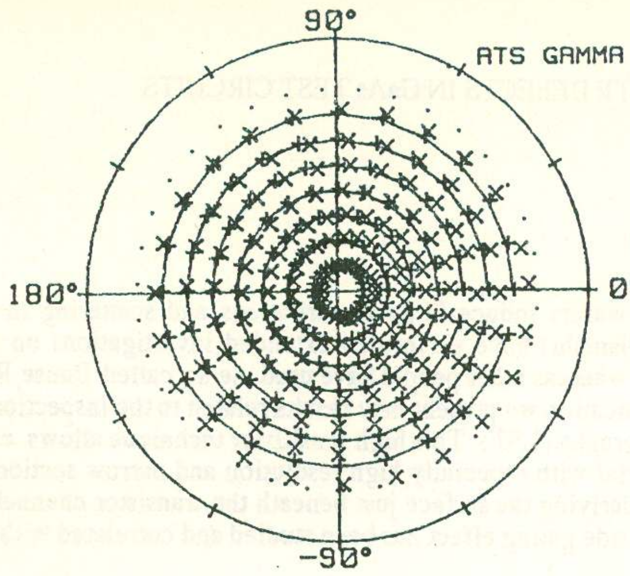


Fig. 2 - The block diagram of the computer controlled set-up (via HP-IB).



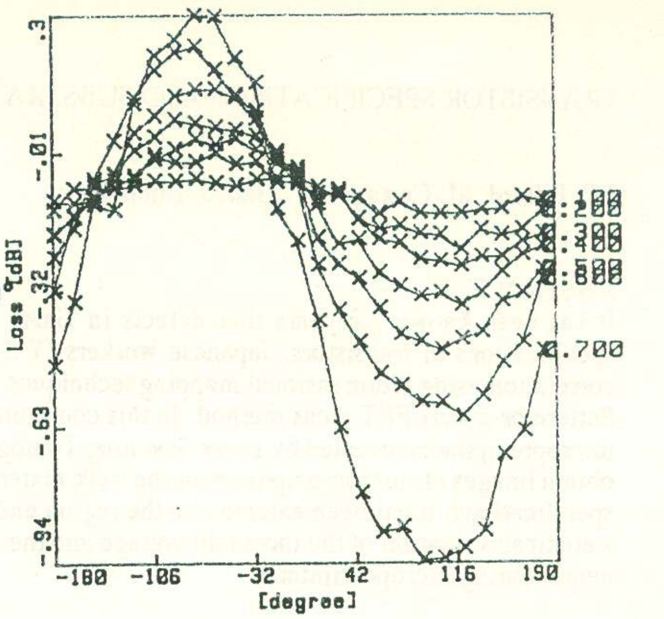


Fig. 3 - Computed and measured values of Γ_s at 8 GHz.

Fig. 4 - Example of the tuner losses $\alpha_{\Gamma s}$ at 8 GHz.

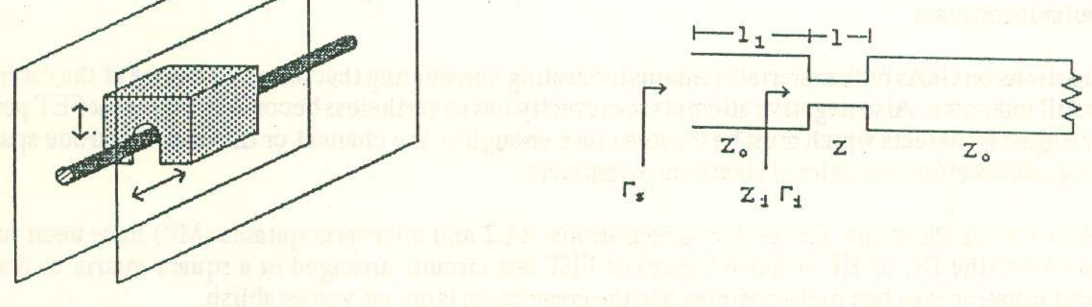


Fig. 5 - Sketch of the tuner and first approximation modelling of the tuner in terms of lossless transmission lines.