A SINGLE SIX-PORT BASED AUTOMATED NETWORK ANALYZER

Souheil Khouaja and Fadhel. M. Ghannouchi

Ecole Polytechnique of Montreal
3333 Queen Mary Montreal, R220.5 PQ H3V-1A2

I. Abstract

A single six-port automated network analyzer (SPANA) is developed built and tested over UHF, L and S band. The SPANA includes a six-port junction operated as two differential channels receiver, and a test set which comprises a network of switches and directional couplers. By comparison to previous developed six-port based network analyzers, the SPANA uses only one single six-port junction and can perform simultaneous power and S parameter measurements with adjust the, test-ports impedances.

II. Introduction

Active and passive microwave circuits are characterized by the measurement of their scattering parameters and generally done using heterodyne Automatic Network Analyzer (ANA) or homodyne six-port automated network analyzers. These instruments, are designed for 50 Ohms line characteristic impedance with 50 Ohms test port impedance. In addition they can not provide accurate power measurements simultaneously with S parameters measurements [1,2,3]. In this paper, we propose a single six-port automated network analyzer (SPANA) capable of performing S parameter measurements while the device under test is seeing an arbitrary impedance which can be changed by the operator without any need to perform a new calibration. Moreover, the SPANA can be calibrated to measure the power flow at both testing ports.

III. Basic Formulation

The main key component of the developed system is the six-port junction operated as a relative two-channel receiver. It is well establish and known that the six-port junction can perform reflection coefficient measurements at the test port while the input port is connected to an RF generator and the four remaining ports to power/voltage detection sensors(see figure 1).

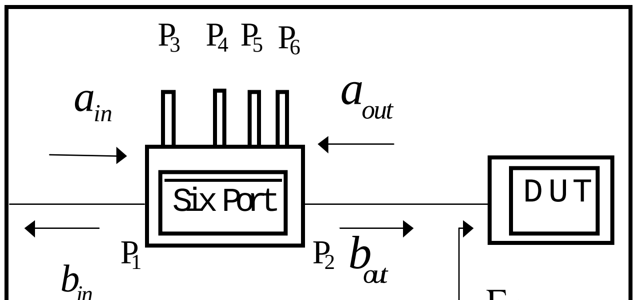


Fig 1 : Six-port reflectometer

In the proposed configuration (see figure 2), incident and reflected waves a_{in} and a_{out} are completely independent and the six port junction reflectometer operated as a wave comparator providing the ratio a_{out}/a_{in}. This ratio as a function of the measured reflection coefficient and the calibration parameters, which have to be determined in advance, as follows :

$$\frac{a_{out}}{a_{in}} = \frac{C_1 \Gamma_{out}}{\left(1 - C_2 \Gamma_{out}\right)} \qquad (1)$$

$$\Gamma_{out} = \frac{a_{out}}{b_{out}} \qquad (2)$$

Where C_1 and C_2 are the calibration parameters characterizing the two-port network constituted by the six-port junction when the four reading ports are terminated by the four power/voltage sensors. These parameters have to be determined in advance.

Γ_{out} is the measured reflection coefficient at port 2 of the six-port junction (see figure 1)

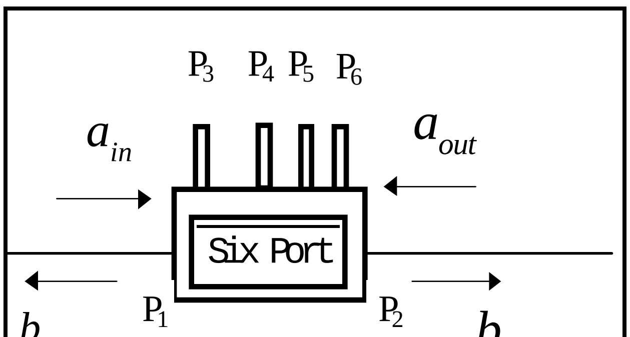


Fig 2 : Six-port comparative waves

IV. Setup Description

The block diagram of the proposed SPANA is shown in figure 3. For S parameter and power flow measurements, the loop 1 is closed using the primary switch network and the incidents and/or reflected waves a_i and b_i are sampled via two-dual directional couplers. Using the secondary switch network, a_i and b_i are routed to the input and output ports of the six-port junction respectively. The S parameters $S_{i,j}$ of the DUT, defined at the two reference ports of the six-port junction are obtained by following this equation :

$$S_{i,j} = \frac{b_i}{a_j} = \frac{C_1 \Gamma}{\left(1 - C_2 \Gamma\right)} \qquad i, j = 1,2 \qquad (3)$$

Γ : Measured reflection coefficient at the output of six-port junction.

For full vector calibration and de-embedding purposes, i., e. to transfer the measurement's reference plane for the inputs of the six port junction to the DUT, several established techniques such as TRL or QSOLT [4, 5] can be used

For the measurements of the source and load impedance seen by the DUT (see figure 3), the setup is configured by opening the first loop which automatically close the second loop. The source (load) impedance Γ_s (Γ_l) is measured by routing the signal generator via the transfer switch to port 2 (port 1) and sampling both incident and reflected waves at port 2 (port 1) to be measured by the six-port junction using the equation 1.

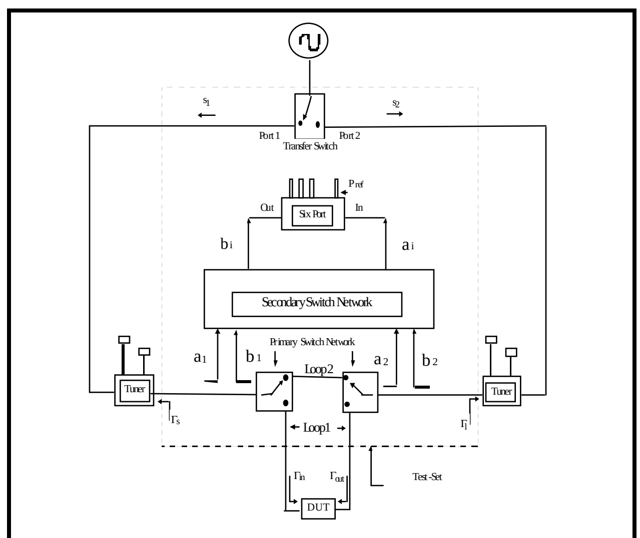


Figure 3 : SPANA Block Diagram

V Measurement Results

Based on the proposed method, a prototype is designed and built which covers

UHF, L and S frequency bands. To validate the approach and to assess the precision of the developed setup, a set of passive and active devices are measured and the results are compared to those obtained using the HP 8753D network analyzer over 0.9-2.7 GHz. Figure 4 shows the S_{21} parameter of 20 dB, 10 dB, 6 dB and 3 dB pad attenuators. Figure 5 shows S_{11} and S_{22} of the NE 76084 GaAsFET. Figures 6a and 6b show the magnitude and phase of S_{21} of the NE 76084 at V_{ds} = 3 V and I_d = 15 mA.

Fig.4: Passive devices S21 : ANA vs SPANA

Fig.5: nec 76084 S11,S22 : ANA vs SPANA

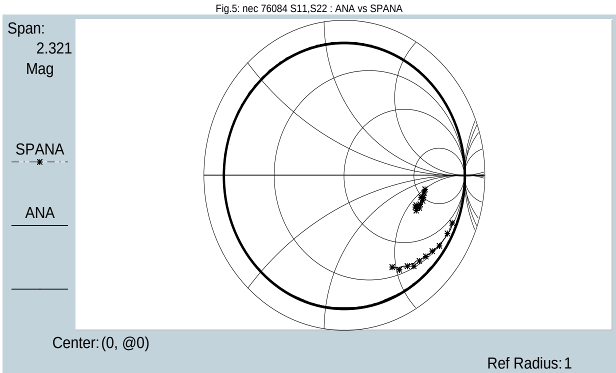


Fig.6a: Nec76084 dB(S21) : ANA vs SPANA

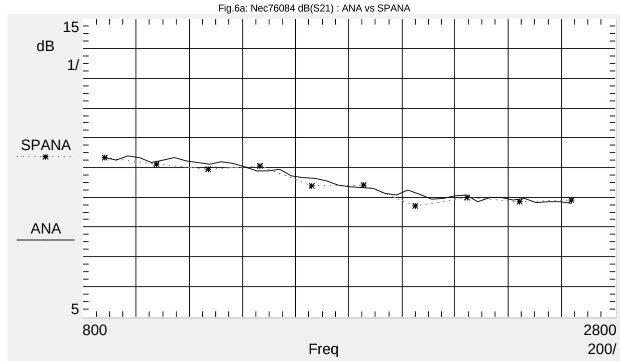
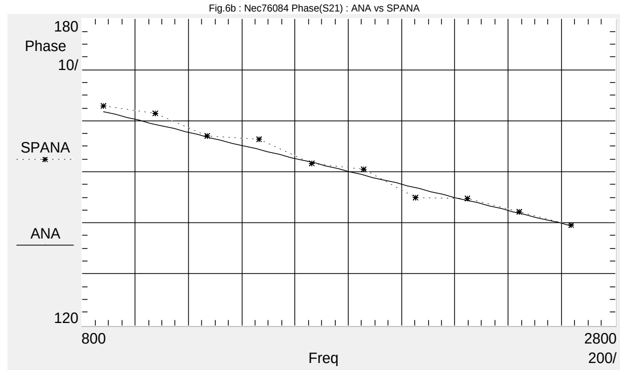


Fig.6b : Nec76084 Phase(S21) : ANA vs SPANA



VI.Conclusion

The developed system is relatively a low cost system, it can be used for S measurements, power flow measurements, source and load impedance measurements. This three capabilities permit also a full large signal characterization (load-pull) of active devices. In addition the system uses only one six-port junction to perform relative wave measurements

0-7803-4471-5/98/$10.00 (c) 1998 IEEE

References

[1] : C.A.Hoer,"The Six-Port Coupler : A New Approach to Measuring Voltage, Current, Power, Impedance and Phase", IEEE Trans, vol IM21, no 4, pp 488-470, Dec 1972.
[2] : G. F. Engen, "The Six-Port Reflectometer : An alternative Network Analyser", IEEE-MTT., vol 25, No 12, Dec 1977, pp 1075-1080.
[3] C.A.Hoer,"A network analyzer incorporating two six-port reflectometers", IEEE Trans. Microwave Theory and Tech, Vol MTT-25, Dec 1977.
[4] G.F.Engen,"Calibrating the six-port reflectometer by means of sliding termination ", IEEE Trans. Microwave Theory., vol 26, pp 951-957, Dec 1978
[5] G.F. Engen ,C.A Hoer"Thrue,-reflect-line : An improved technique for calibrating the dual six-port automatic network analyzer", IEEE Trans. On MTT., vol. 27,December 1979, pp.987-993.