SIX PORT MEASUREMENT SYSTEM CONTROL

Ing. Tomáš URBANEC, Doctoral Degree Programme (4)
Dept. of Radio Electronics, FEEC, BUT
E-mail: urbanec@feec.vutbr.cz

Supervised by: Prof. Jiří Svačina

ABSTRACT

The paper presents software for measurements with the six port measurement system. All of the necessary tasks are implemented, such as detector linearization, power calibration, six-port calibration evaluation. For the measurement itself the software offers all of the standard displays as return loss and phase vs. frequency etc.

1 INTRODUCTION

Vector microwave measurement is necessary in a lot of cases and then problems arise, because classical vector network analyzer (VNA) is very expensive. For the vector measurements there is also the possibility to use the simple six-port measurement system, but proper software for evaluating parameters of the six-port and results is absolutely necessary.

2 BASIC PRINCIPLE

In the 1970th there was published the principle of the measurement method by G.F. Engen [1]. On the port 1 there is connected the microwave generator, on the port 2 the unknown impedance. On the ports 3 to 6 there is measured the incidental power with preferable diode detectors.

For the port 2:

$$\rho = a_2 / b_2 \quad, \tag{1}$$

where ρ is reflection coefficient on the port 2, a_2 and b_2 are reflected and incidental wave at the port. In the case of microwave six-port is linear general circuit, there could be written:

$$P_3 = \left| A \cdot a_2 + B \cdot b_2 \right|^2 \quad, \tag{2}$$

where P_3 is observed power on the port 3 and A, B are complex coefficients, which describe the six-port. The same could be written for ports 4-6 and powers P_4, P_5 and P_6.
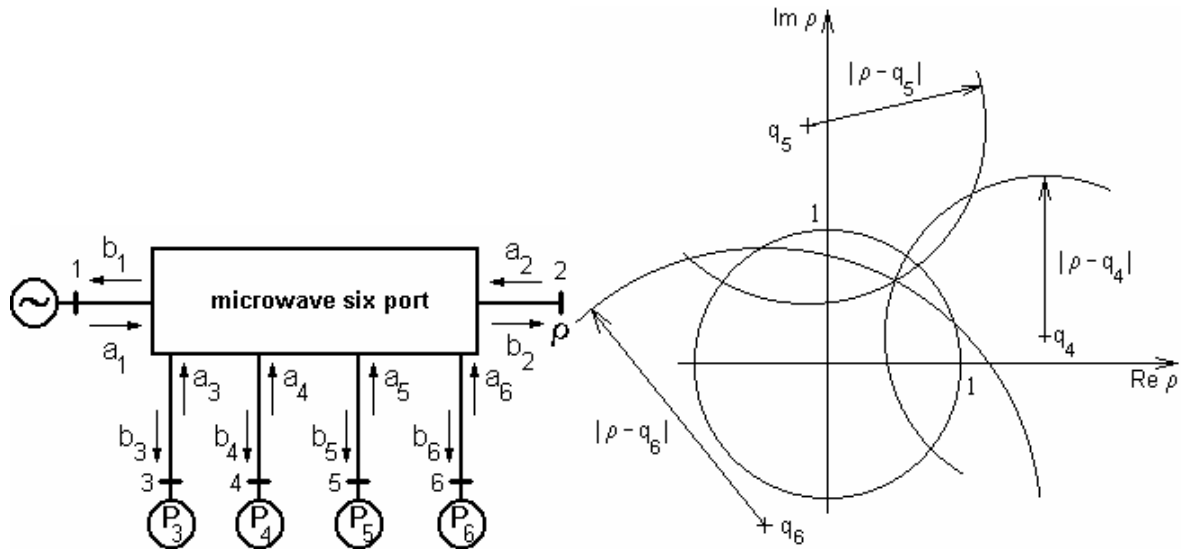
Fig. 1:   *a) Basic arrangement of the six-port; b) Geometrical interpretation of the formulas (7), (8) and (9)*

For the practical reasons, there it is good to state for the one of measuring ports, that the power is dependent only on the power from generator, not on the reflected from unknown termination

$$P_3 = \left| B \cdot b_2 \right|^2 \quad . \tag{3}$$

With the use of (1) there could be written then

$$P_4 = \left| C \right|^2 \cdot \left| b_2 \right|^2 \cdot \left| \rho - q_4 \right|^2 , \tag{4}$$

and similarly for other two ports:

$$P_5 = \left| E \right|^2 \cdot \left| b_2 \right|^2 \cdot \left| \rho - q_5 \right|^2 , \tag{5}$$

$$P_6 = \left| G \right|^2 \cdot \left| b_2 \right|^2 \cdot \left| \rho - q_6 \right|^2 . \tag{6}$$

From (3) we can use the b_2 in the evaluations (4) to (6) and so we get

$$\left| \rho - q_4 \right|^2 = P_4 / P_3 \cdot \left| B/C \right|^2 \tag{7}$$

$$\left| \rho - q_5 \right|^2 = P_5 / P_3 \cdot \left| B/E \right|^2 \tag{8}$$

$$\left| \rho - q_6 \right|^2 = P_6 / P_3 \cdot \left| B/G \right|^2 \tag{9}$$

As can be seen in the Fig.1b, formulas (7) to (9) forms circles and the result is in its intersection, ideally it is just one point, which identifies the result of measurement. Practically due to the measurement error, noise and other influences, there is a small area between those three circles.

3   ACQUISITION CIRCUITS

The measurement of the microwave powers in the six-port is done by diode detectors, which are integrated on the board of six-port. It serves two purposes. At first it eliminates

poor reproducibility of measurement with connectorized detectors and will work as its low cost replacement. At second, the small dimensions of the six-port and detectors allow the use of eventual temperature stabilization.

The detected signals are amplified and inverted if necessary. For the data acquisition and A/D conversion is used development kit for CPU C8051F020 from Cygnal manufacturer. The CPU has integrated 12-bit wide A/D converter with up to eight multiplexed channels and also selectable gain for them. Communication with steering and computing PC is done by serial line with the speed of 115 200 bps.

4 LOW LEVEL ACQUISITION SOFTWARE

It was necessary to write the proper software for acquisition board. First set of tasks is conditioning the microprocessor itself:

- configuration of CPU, oscillators, necessary peripheries

- initialization of serial line RS232C, A/D converter, temperature sensor

Next follow the main subroutines, which are the FIFO buffer for serial line and A/D channels reading. The temperature measurement of the CPU it is implemented also. The whole measurement is commanded by the PC.

- The set of commands contains:

- selection of active channels of A/D converter

- gain setting of every A/D converter channel

- averaging count selection for noise reduction and accuracy improvement

- sending of measured data to PC

5 MAIN COMPUTING SOFTWARE FOR THE PC

The main program it is written in the Agilent VEE Pro ver.6.2 development environment. It offers very easy to use graphical programming technique with the all of the necessary program blocks prepared for the use. Programming is made by placing the function blocks of program and its interconnecting with the signal flows.

Core of the program is the main menu, which offers all the necessary subroutines for the six-port.

First is the subroutine for the setting of communication, active channels of A/D converter etc.

Second block is liable for detector calibration. This is necessary due to the nonlinear characteristic of diode detector. It is realized by the generator with the variable power output, which is commanded via the GPIB bus. The accuracy of that calibration measurement is limited with the accuracy of the generator output. Sufficient amount of the measured points is fitted with the polynomial curve of sixth degree which offered the best results.

Third block is the evaluation of the calibration constants for the used six-port. It is not practical to compute them from the evaluations (7) to (9). It is possible to define those

constants with the following equation:

$$\rho = r + jx = \frac{\sum_{i=1}^{4}(F_i + jG_i)\cdot P_i}{\sum_{i=1}^{4}H_i \cdot P_i} \quad , \tag{10}$$

where F_i, G_i, H_i are the real constants, P_i are measured powers on detectors and r, x are unknown real and imaginary part of the measured impedance. The equation (10) can be separated on the real and imaginary part and we get:

$$\sum_{i=1}^{4}F_i \cdot P_i - r \cdot \sum_{i=1}^{3}H_i \cdot P_i = r \cdot P_4 \quad , \tag{11}$$

$$\sum_{i=1}^{4}G_i \cdot P_i - x \cdot \sum_{i=1}^{3}H_i \cdot P_i = x \cdot P_4 \; . \tag{12}$$

The equations (11) and (12) form the set of eleven equations with the eleven unknowns, when you assume, that one of them, let say H_4, can be set to 1. With the help of proper group known impedances it is possible to evaluate the constants F_i, G_i, H_i.

Last block offers set of standard displays of the computed impedances vs. frequency with the help of previously computed and saved calibration constants. There are also displays for viewing raw data from six-port for further evaluation of parameters and power display, which is necessary for the computing the six-port unknowns. Those power curves it is possible to save to a file for the use in the previous described calibration block. In the Fig.2 can be seen the measurement in the Smith chart display. Measured data are for coaxial line ended by open circuit.
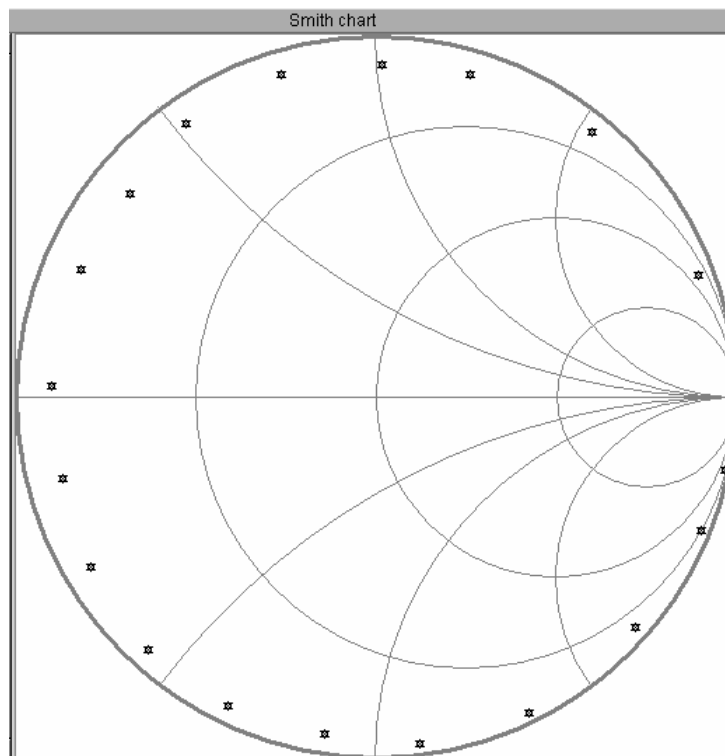

Fig. 2:   *Measurement display of Smith chart*

6 CONCLUSION

The basic principle of the six-port vector analyzer was presented. The simple acquisition circuit was presented with necessary subroutines for data sending to PC. Program for PC was discussed and essential subprograms were described. At the end the typical measurement was shown.

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