A NEW APPROACH TO THE DESIGN OF WIDE-BAND MULTIPROBE REFLECTOMETERS

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Abstract

A new design approach for low-cost multiprobe reflectometers is presented. While traditional circuits adopt equally-spaced probes, the presented solution provide a method to greatly enhance the bandwidth of the measuring system by a proper choice of each probe position. As example, a five-probe 0.6-16 GHz system has been designed.

Introduction

Modern automatic network analyzers use complex and expensive heterodyne and mixing circuitry to determine amplitude and phase of unknown reflection coefficients at microwave frequencies. The developement of six-port reflectometers have provided an alternative method, which reconducts the problem to the measurements of power ratios. Six-port systems [1] still require many directional couplers and hybrids and they are quite complicated. The simplest method is probably the multiprobe reflectometer, which consists in sampling with fixed probes the standing wave pattern on a transmission line which feeds the device under test. This solution can be easily built in microstrip and monolithic version [2], providing a really low-cost way to have reflection coefficient informations inside larger subsystems. Equally-spaced probes can be easily design to operate at a single frequency or for small bandwidth applications [3]. In order to extend the operating range, Chang et al. [4] proposed to raise the number of probes and to modify the spacing between them, but a general design method has not been presented yet.

Here a novel approach is investigated, which allows to obtain the probe positions as a function of the required bndwidth. To validate the method, comparisons were made with the results already published in the case of equally-spaced probes.

Theory and design approach

Figure 1 shows a simplified scheme of the measurement setup. Probes, transmission line and coupler can be seen as a generic multiport junction, whose theory has already been developed for six-port system [1]. For each probe, a simple equation can be written to relate the detected power P_i with the unknown reflection coefficient Γ_L [4]. It can be proved that the obtained set of equations, that we regard as the *measurement equations*, is a linear system provided that

$$\Gamma = \left[|\Gamma_L|^2 \quad \mathrm{Re}(\Gamma_L) \quad \mathrm{Im}(\Gamma_L) \right]^T \tag{1}$$

is chosen as the vectors of unknowns.

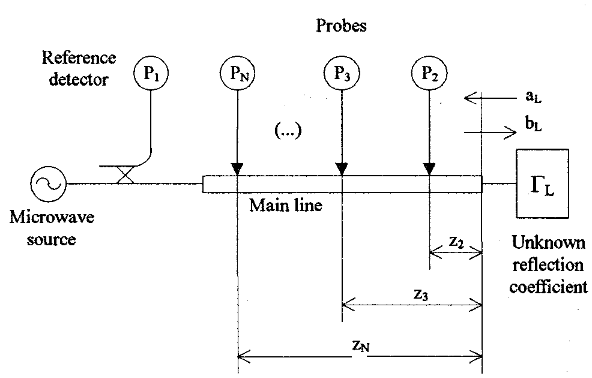

Fig. 1. Simplified measurement scheme

The performance of the multiprobe system was studied analyzing the *condition number* of the measurement equations, as defined in [5]. In particular, given a specified bandwidth, the adopted algorithm minimizes a proper mean condition number computed over the required range of frequencies.

Simulation results

The proposed approach gives results that are coherent with what found in literature for equally-spaced probes. Figure 2 shows the condition number for a three-probe reflectometer as a function of the constant spacing (expressed as electrical length). The curve minimum is for $\Delta\phi = 120^\circ$, as well-known from the six-port theory. Chang et al. [4] regard as acceptable a shift greater than 60° and slightly less than 180° over the operating bandwidth; since in this range the condition number is less than 7, this value was assumed as a reasonable specification for our design.

By using more than three probes and optimising their positions for a minimum condition number, a broader bandwidth is obtained. Figure 3 shows the condition number for the optimum equally-spaced five-probe reflectometer (spacing $\Delta\phi = 72^\circ$) as a function of the normalised frequency. Figure 4 shows the condition number of the unequally-spaced five-probes reflectometer (spacing: 219°, 648°, 772°, 950°). Bandwidth performance appears to be greatly enhanced in the latest case with respect to both three and five equally-spaced probes. A 600 MHz - 16 GHz microstrip prototype has been realised and measurement results will be available at conference time.

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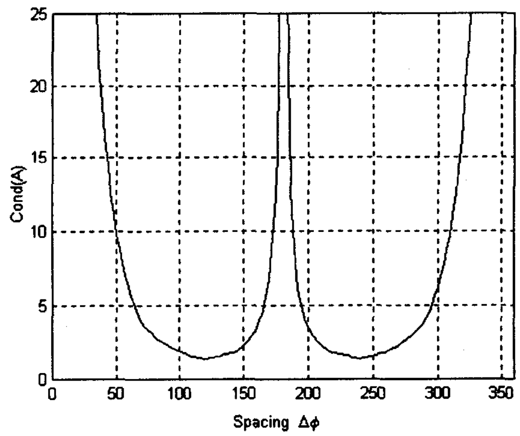

Fig.2. Conditioning for a three equally spaced probe reflectometer as a function of the probe spacing.

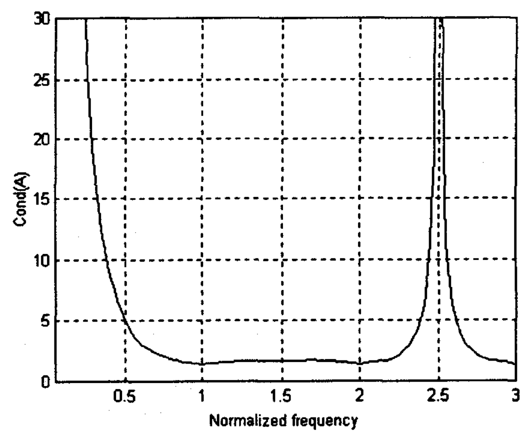

Fig.3. Conditioning for the optimum equally spaced five-probe reflectometer.

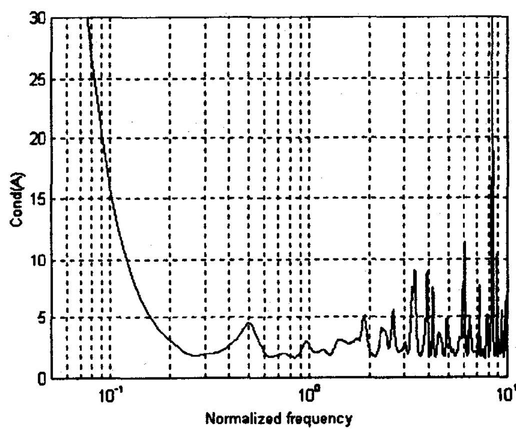

Fig.4. Conditioning for the optimum five-probe reflectometer designed according to the presented criteria.