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SIMPLE TECHNIQUE FOR SOURCE REFLECTION COEFFICIENT MEASUREMENT WHILE CHARACTERIZING ACTIVE DEVICES

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ABSTRACT

This paper describes a simple, yet rigorous technique for fast and accurate determination of the source reflection coefficient during the characterization of microwave active devices. The solution consists in measuring the waves at the DUT reference plane under two different bias conditions. Since the DUT small signal impedance value depends on the bias voltage, the waves at the DUT input port changes as well. We proved that their measurements give enough information to compute the source reflection coefficient with accuracy suitable for most applications. The correction for systematic errors is based in the traditional error-box model and it does not require any exotic calibration procedures. Experimental results are presented and compared to data obtained with more traditional techniques.

PROBLEM DEFINITION

Microwave source-pull measurement techniques consist in monitoring the desired performance of the device under test (DUT) while driving it with different source impedance values. This approach is widely used for microwave active device characterization, both in small and large signal conditions. A typical application is low noise amplifier (LNA) design to experimentally obtain the optimum noise impedance [1] or the matching network for mixers, oscillators and high efficiency amplifiers [2 - 5].

Figure 1 shows the simplified block scheme of a traditional test-set for both source and load-pull characterization of active devices. Two reflectometers measure the waves at the DUT reference planes, while two tuners set the source and load conditions at the input and output ports, respectively. Traditional measurement systems are able to obtain calibrated values of a_1 and b_1 and their ratio

$$\Gamma_{in} = \frac{b_1}{a_1} \tag{1}$$

On the other side, the source reflection coefficient Γ_s is defined as

$$\Gamma_S = \frac{a_1}{b_1}\left(1 - \frac{a_S}{a_1}\right) \tag{2}$$

Obviously Γ_s it is equal to ratio a_1/b_1 only if $a_s = 0$, i.e. the internal generator is switched off.

A simple technique for measuring Γ_s is suggested in [6] for not unilateral DUT (i.e. $s_{12} \neq 0$). First, the DUT is excited from port 1 and its input gamma is computed by eq.(1). Then, the source signal is turned to port 2 and a second acquisition of waves a_1, b_1 is performed. From (2), the source reflection coefficient is simply the ratio $\Gamma_S = a_1/b_1$, since now the source term a_s is null.

A completely different approach is described in [1],

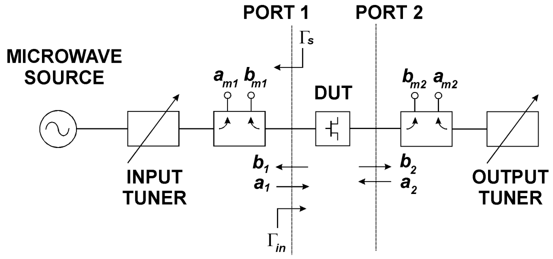

Fig.1. Simplified block scheme of a traditional test-set for both source and load-pull characterization of active devices.

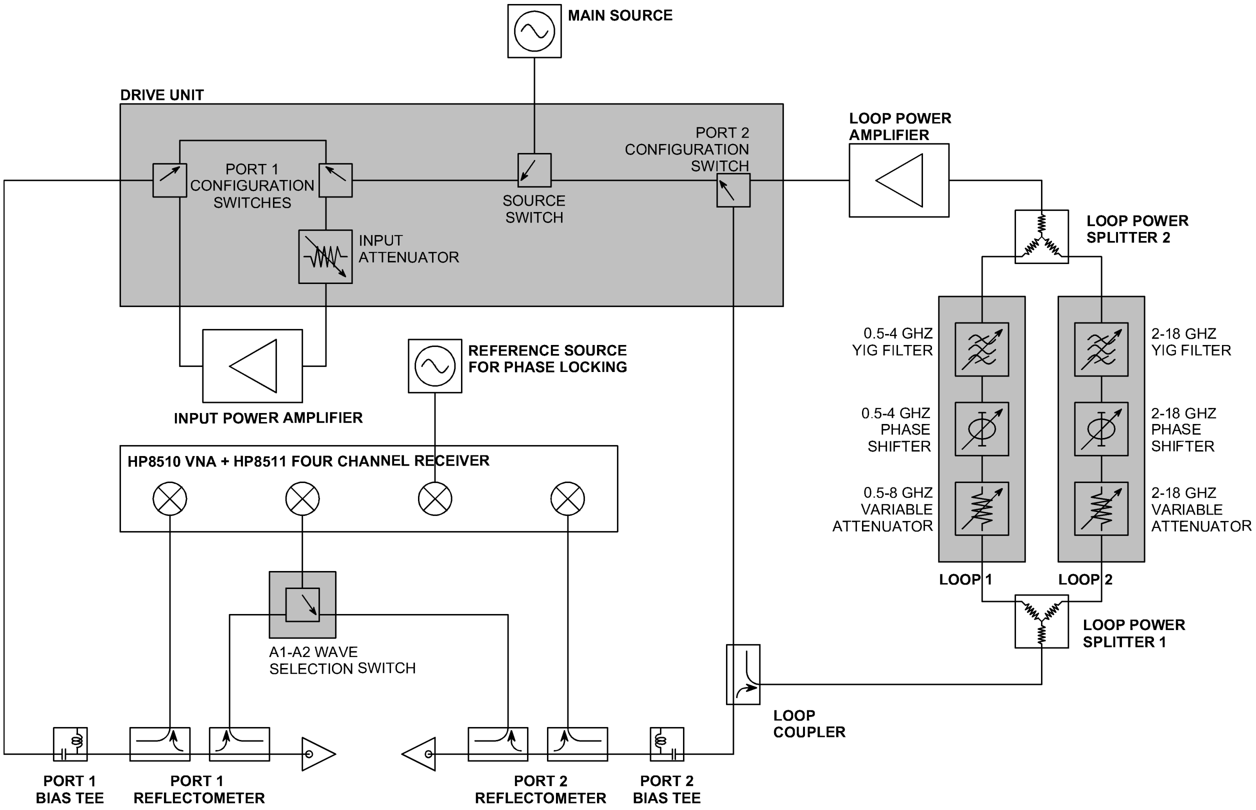

Fig.2. Commercial harmonic active load pull system used to verify the novel measurement technique. Different source reflection coefficients were set by a passive tuner at port 1.

where the reflection coefficient of the tuning element is continuously monitored by a six-port reflectometer in reverse configuration. This technique is both accurate and suitable for automatic source pulling; however, the problem is just diverted, since now it is the DUT reflection coefficient Γ_{in} that cannot be determined.

The method presented in [7] solves the latter problem. The microwave signal is first injected before the reflectometer to measure the DUT input characteristic; then, it is switched immediately after, in order to measure the source reflection coefficient in the reverse configuration.

Common feature of all the previous approaches is that they measure the DUT and the source reflection coefficients by two different steps, and they involve switching the microwave source signal. For fast and automatic characterization of active devices, this can be time consuming. The authors recently proposed a new technique based on the concept of a three-sampler reflectometer [8], which allows the simultaneous determination of source and DUT input gamma. This technique is indeed fast and accurate, but it is based on unconventional error model and it requires a special purpose calibration procedure.

NOVEL SOLUTION

The solution here proposed is a simple, yet rigorous technique for determining the source reflection coefficient while characterizing active devices. Briefly, it consists in measuring waves a_1, b_1 at the DUT input reference plane under two different DUT bias conditions (obtaining a_1', b_1' and a_1'', b_1''.). Assuming that neither the source signal a_S nor Γ_S changes in the two situations, two equations like (2) are stacked to form a simple linear system in the unknowns a_S, Γ_S . Its solution gives

$$\Gamma_s = \frac{a_1' - a_1''}{b_1' - b_1''} \tag{3}$$

The novel technique has some noteworthy features:

- it is rigorous, since it is not based on the repeatability of a microwave source switch;
- it is safe and suitable for source and load pull characterization of unilateral devices, since it does

not require to excite the DUT back from port 2 (as required in [6]);

- it is flexible, since it can be successfully applied to different source pull test-set configurations;
- the correction for systematic errors is based on the traditional error-box model and it does not require any exotic calibration procedures.

The technique was successfully applied to measure the source reflection coefficient during harmonic load-pull HEMT characterization. A commercial 0.5-18 GHz active load-pull system was used, as shown in figure 2. The measurement setup is based on a traditional vector network analyzer, used as a four-channel microwave receiver. A passive tuner set the source reflection coefficient. Vector corrected waves at the DUT input port were obtained by the same calibration procedure already implemented in the system software. Figure 3 shows some experimental results obtained by the new method and the technique described in [6].

CONCLUSIONS

A novel technique has been presented to measure the reflection coefficient of the microwave source while characterizing active devices. Due to its simplicity, the technique is an interesting solution that can be applied in several situations. The accuracy experimentally shown against traditional methods is sufficient for most of applications.

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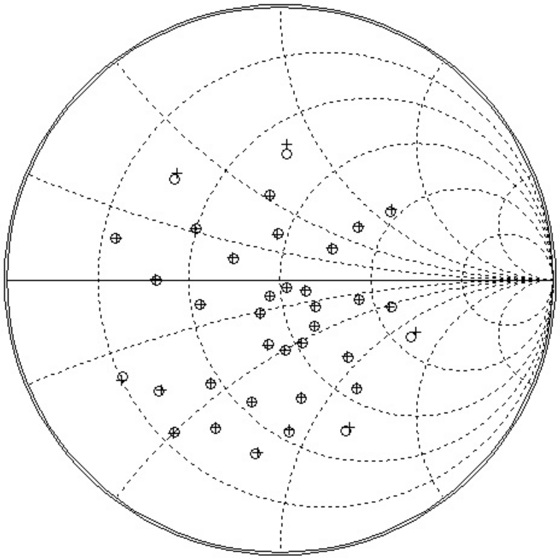

Fig.3. Source reflection coefficient at 6 GHz for various tuner positions computed by the approach of [6] (+) and by the novel technique (∘).