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Application Note 28B

V- and W-band On-Wafer HEMT Noise Parameter Measurements

Automatic setups accurately measure the four Noise Paramerters on-wafer of transistors and MMIC's in V- and W- frequency bands (50-75 and 75-110 GHz respectively). The setups use *waveguide* programmable tuners model 7550 and 11075 and *biasable* waveguide probes model 75 and 120 of GGB Industries. The systems use the *cold noise source* measurement method.

Introduction

Automatic Load Pull or Noise measurements require accurate knowledge of the tuner's and the setup's parameters. The classical technique used by Focus Microwaves consists in measuring each component separately on the Network Analyzer, including the tuners and the other passive components of the setup (bias tees, isolators, attenuators as well as test fixture). In the case of a wafer probe setup the test fixture consists of the two cables connecting the tuners to the probes and the probes themselves. The TRL software, used by Focus Microwaves permits to extract the S-parameters of the two halves of the "Wafer Test Fixture" and use them in the setup corrections and de-embedding.
This approach offers the advantage of not having to tie up a Vector Network Analyzer permanently to the setup during the measurement.

There is however justified concern about the accuracy of the measurement when the setup has to be broken apart after the calibration and put back together at another loca-tion using only the pre-calibrated tuner and setup data from files stored in the hard-disk. The possible error increases especially in the case of "on wafer" testing since the losses of traditional wafer probes are higher than the losses of test fixtures, and this implies also much higher reflective loss (At Γs=0.9 the reflective loss of the test fixture is about 10 times the S_{21} [1] and so is the uncertainty of the measurement, figure 3).

In the case of Noise measurements the measurement uncertainty at the input of the setup due to high loss can be eliminated using the "Cold Noise Source" method [2].

The setup and associated theory used to make accurate on wafer noise and load pull measurements are presented together with measured data.

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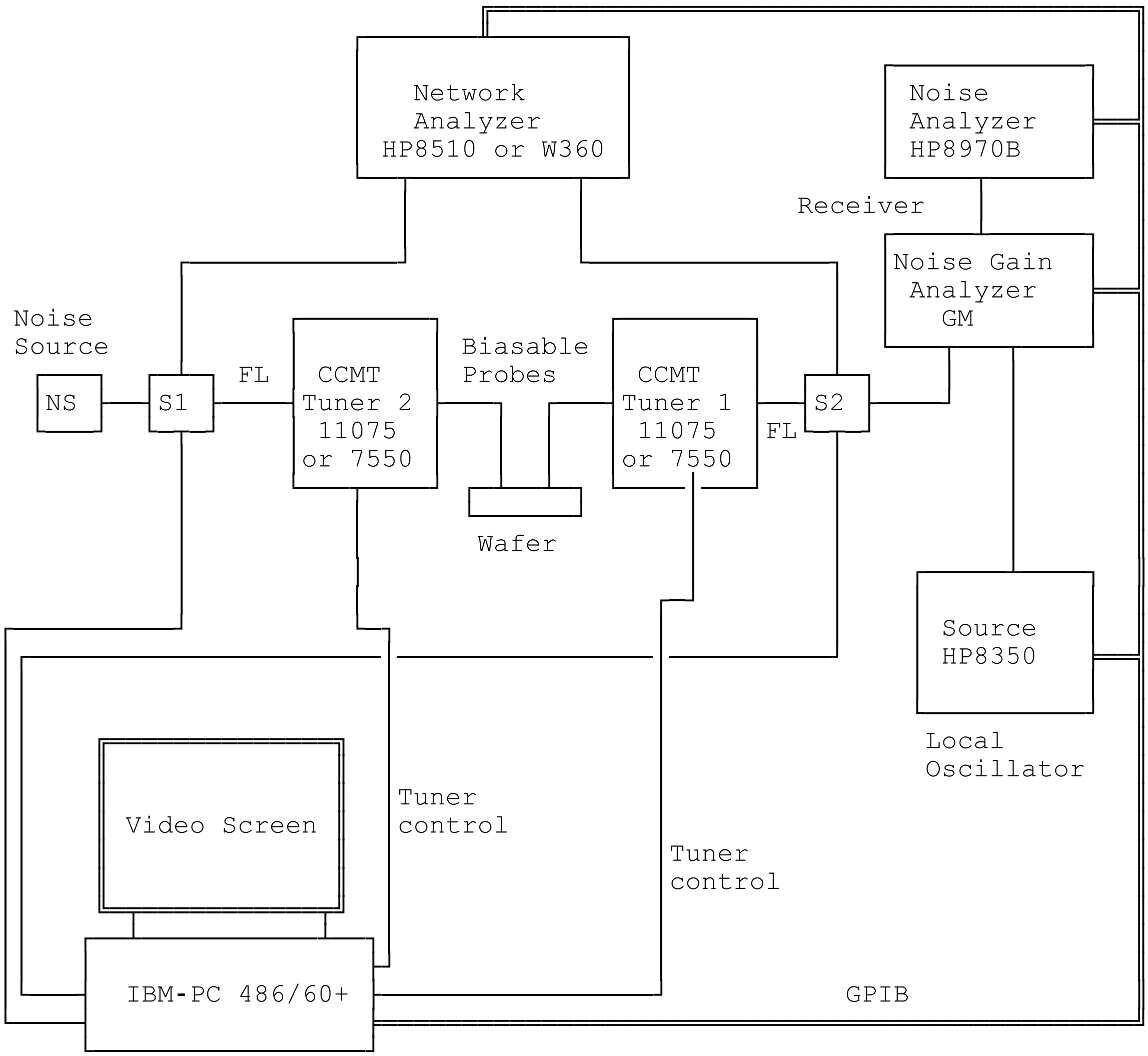

Legend: NS = Waveguide Noise Source (Millitech or Noisecom)
S1,S2 = Remotely [x] or manually controlled WR-10 or WR-15 SPDT switches
FL = flexible waveguide sections.
Biasable waveguide probes model 75 or 120 (GGB)

The measurement setup consists of two programmable tuners model 7550 for 50 to 75 GHz (V-band) or model 11075 for 75 to 110 GHz (W-band), a Vector Network Analyzer (Hewlett-Packard 8510 or Wiltron 360 with millimeterwave extension hard- and software), a noise analyzer HP-8970B and a noise source, a wafer probe station with biasable waveguide probes model 75 for V-band and 120 for W-band and two SPDT switches either remotely controlled by the system PC or manual, all covering the frequency range of interest. The setup is remotely controlled by an IBM®PC compatible controller with tuner controller and GPIB interface.

System Calibration

In order to avoid the break-apart and reassembling errors of the setup we have to calibrate the critical sections between the bias tees and the wafer probe tips "in-situ".

The first step consists in performing an accurate coaxial calibration of the Network Analyzer on ports A and A'. For this we recommend to use, if possible coaxial TRL calibration kits, available from different vendors, such as Focus Microwaves [3] and Hewlett Packard [4].

We then connect both ports of the setup (B and B') to the Network Analyzer ports A and A' and characterize the complete setup as an extended test fixture using a modified version of Focus' SETUP software package.

This programm permits to characterize any test fixture by measuring the S-parameters of a Thru Line, a Delay Line and a Reflect, connected to the probe tips. All major wafer probe manufacturers supply this type of TRL standard for the various frequency ranges up to 40 GHz and above.

The result of the TRL characterization of the setup consists of two sets of S-parameters, one for the section between B and D and the other between D' and B' (figures 1 and 2) saved in binary form on the hard-disk as a function of frequency. For this step both tuners are set to zero (RF probe extracted) in which case they represent almost ideal
50 Ω transmission lines.

We then calibrate each tuner with the probe tips connected to a Thru Line and the other tuner in the zero position (50 Ω transmission).
During vertical scaling and tuner calibration the effect of the opposite setup side is simultaneously de-embedded, so we measure the four S-parameters of each half of the setup, including tuner, separately.

The calibration is fully compatible with existing tuner calibrations but the data are more accurate because we do not need to break the setup apart any more before we can proceed to measurements. We only have to disconnect the Network Analyzer cables from ports B and B' and connect them to C and C'.
This can be done also automatically by using remote control SPDT RF switches (SW) as shown in figures 1 and 2.

Using RF switches or disconnecting the setup at points B and B' is not very critical, because the source and load impedances at these points of the setup are close to 50 Ω and we operate in a non-critical Loss region (figure 3).

This calibration method also permits to measure "in-situ" the S-parameters of the DUT, if we insert it in the wafer probe station and de-embed with the previously computed S-parameter matrices of the two halves of the setup. The S-parameters of the DUT are required in Noise Measurements in order to correct for the second stage noise contributio, following Friis' theorem [2].