Application Note No. 008

Measure 3 Types of Parameter and You will Define a Small Signal RF-Transistor: S-Parameters, Noise Figure and Intermodulation

RF & Protection Devices

Never stop thinking

Edition 2006-11-14

Published by
Infineon Technologies AG
81726 München, Germany

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Revision History: 2006-11-14, Rev. 2.0

Previous Version: 200-07-27

Page	**Subjects (major changes since last revision)**
All	Document layout change

1 Measure 3 Types of Parameter and You will Define a Small Signal RF Transistor: S-Parameters, Noise-Figure and Intermodulation

With the increasing need to reduce development time, RF designers are increasingly employing simulation tools which need accurate device data. This note is intended to help understand the origin of the values required and to reconstruct a similar setup for own analysis and verification.

1.1 S-Parameter measurements

1.1.1 Using a test fixture

S-Parameters of Infineons FETs or bipolar transistor are usually measured in a common source or common emitter configuration in a precision 50 Ω test fixture. A full 2-port calibration using 7 mm cal kits must be performed at the ends of the measurement cables. In order to obtain a calibration at the reference plane of the transistor, the coefficients of the 12 term calibration are retouched by the controller using the known S-Parameters of the test fixture.

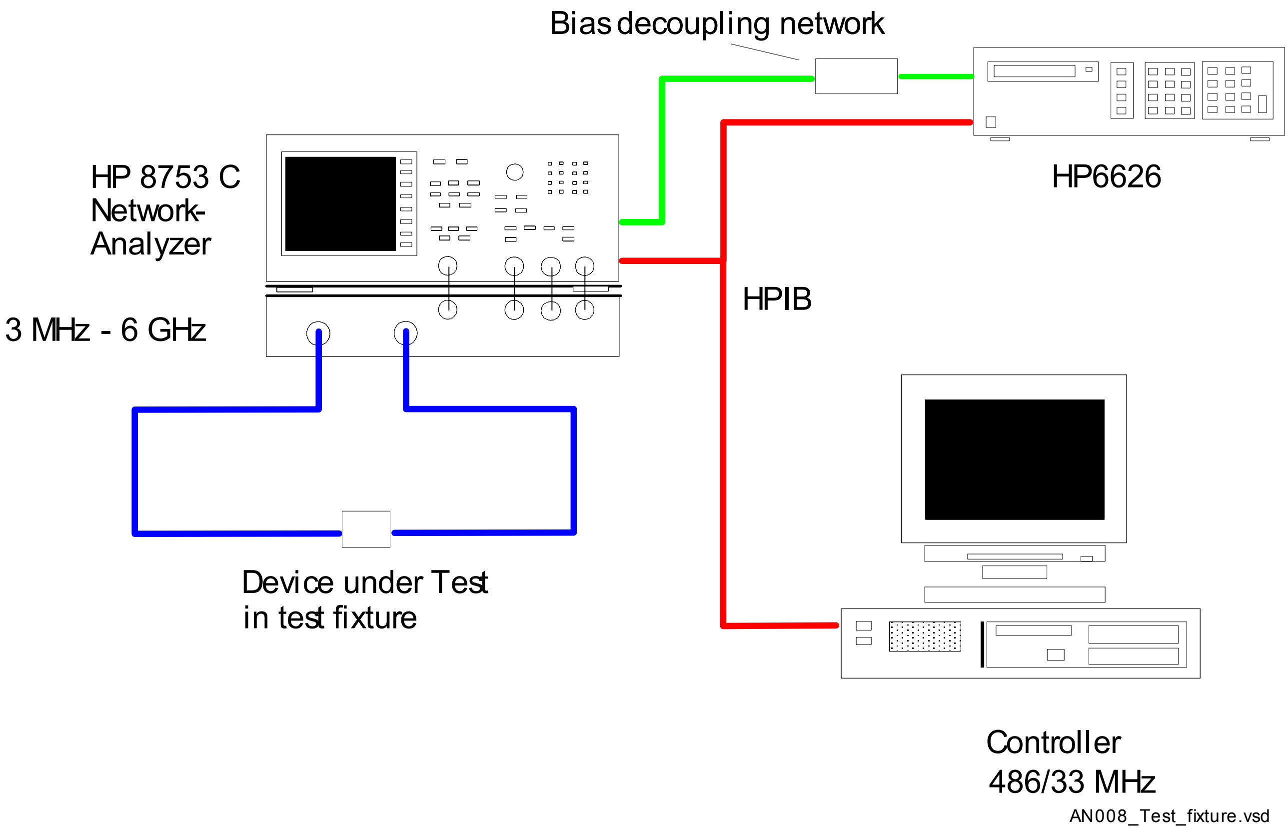

Figure 1 Test fixture

Port 1 attenuation must be set high enough to ensure small signal operation of the DUT even at lowest collector currents and lowest frequencies. Noisy readings can be avoided by 20 dB less attenuation at port 2 and a very narrow IF bandwidth setting.

The HP6626 bias sources are connected according to HP application note 376-1, which describes the advantage of applying the collector-base voltage and the direct setting of the emitter current. An additional bias decoupling network prevents LF oscillation in the bias circuit.

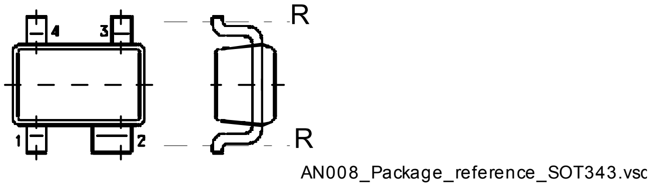

Figure 2 Reference plane for S-parameters of SOT343 packages

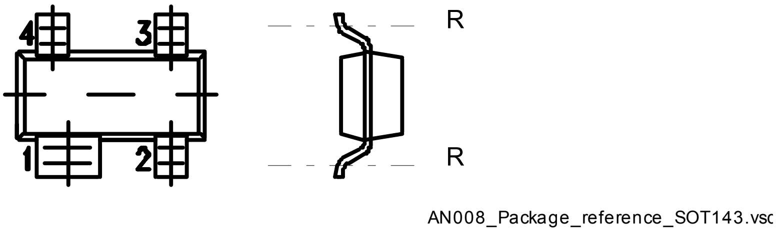

Figure 3 Reference plane for S-parameters of SOT143 packages

1.1.2 Using microstrip boards

Some customers may wish to check a transistor's S-Parameters on a microstrip board using cheap SMA jacks. After a calibration with a 3.5 mm cal. kit, the length between connector and transistor is corrected utilizing the analyzer's electrical delay function. Connector discontinuities, microstrip impedance errors and losses are neglected.

A more accurate method is to perform a TRL calibration with the appropriate standards, an accurate 50 Ω stripline and special connectors.

A further problem with such methods is that the emitter grounding-via acts as a small negative feedback which is not included in the data sheet S-parameters.

1.2 Noise Figure measurement setup for transistors as DUT

The setup described (**Figure 4**) is useful up to 2000 MHz with no mixer between pre-amplifier and NF-meter. The transistors are measured in a precision text fixture. Source impedance is tunable to the minimum noise figure, the load impedance to maximum gain. The use of circulators can be avoided reducing the noise diodes impedance shift by a 10 dB attenuator and by using a pre-amplifier with a low input reflection coefficient.

One way of omitting a special cal path is to interconnect the tuners in a 50 Ω position directly without DUT. In this case the ENR table values have to be entered diminished by the loss between noise diode and DUT. The additional transformation losses resulting from the use of high-Q tuners can be neglected in most cases for BJT-measurements.

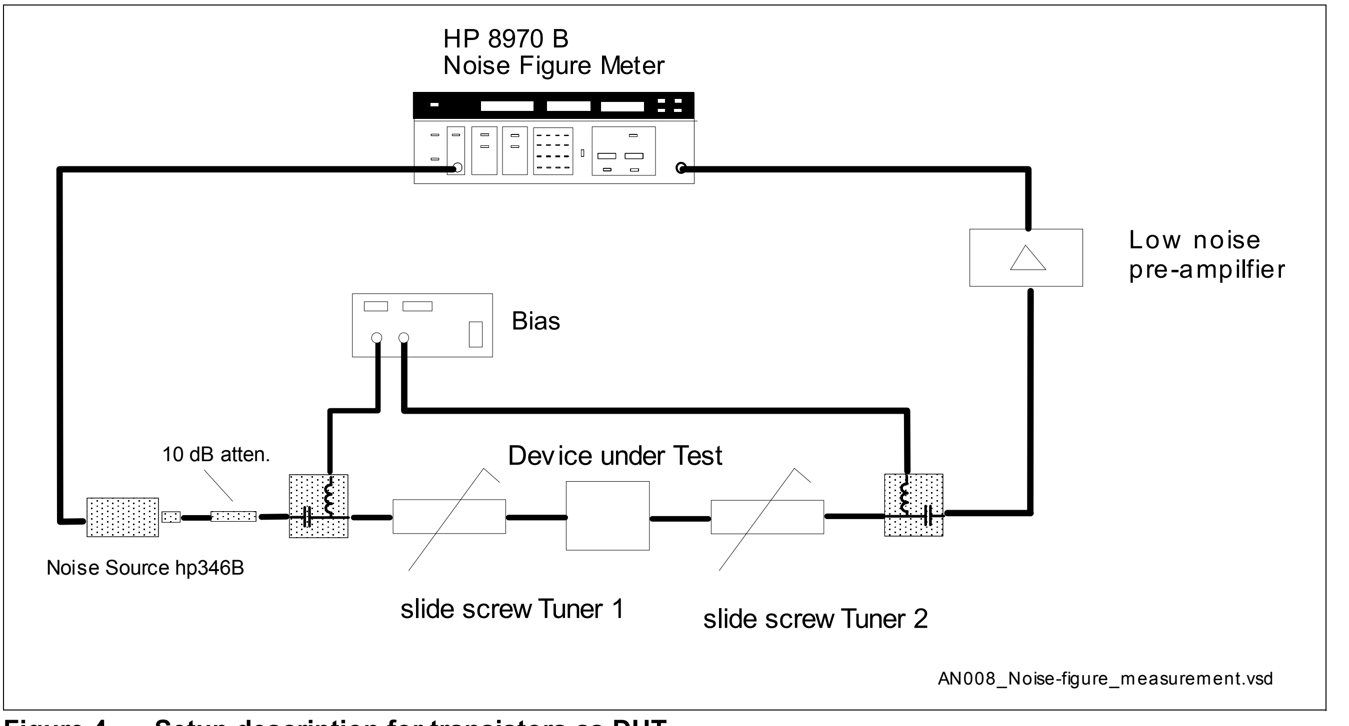

Figure 4 Setup description for transistors as DUT

1.3 Noise Figure measurement setup for mixers as DUT

The frequency shift of ENR values for calibration and the display of the true measurement frequency is provided by the meters noise figure setting (SP 1.3) sideband selection (SP 2.1 or 2.2) and input frequency f_{IF} (SP 3.0). One combination of f_{LO} and f_{IF} is the wanted measurement frequency - the other one is an interfering mirror frequency at a distance of 2 x f_{IF} which has to be suppressed by a filter (e.g. variable bandpass).

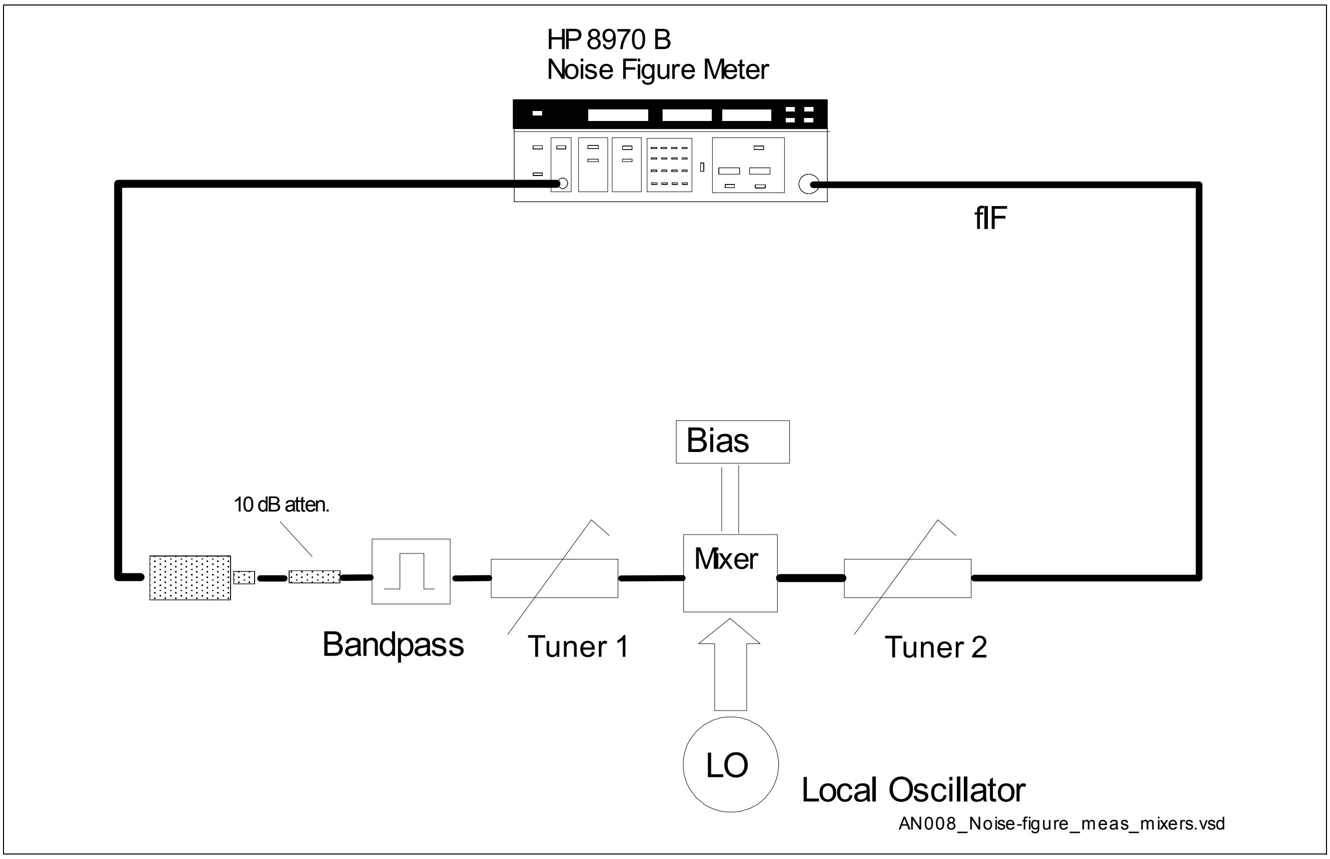

Figure 5 Setup description for mixers as DUT

As the LO's contribution to the noise figure is not removable by any kind of calibration, it is very important to use a generator of high spectral purity and low phase- and AM-noise (e.g. tube oscillator or quartz-oscillator).

1.4 Intercept point measurements

Although the rule of thumb $IP_{3out} = P_{-1dB}$ + 10 dB suggests the use of the compression point P_{-1dB} as a replacement, the direct characterisation of the intermodulation is strongly recommended. In practice the operating conditions are hardly comparable as IP_{3out} is a class A parameter, whereas P_{-1dB} is a transmitter parameter influenced by high-power effects.

The 3rd order distortion of the DUT generates IM products at 2f1-f2 and 2f2-f1. IP_{3out} is defined as the intercept point of an extrapolated 3rd order IM product with an extrapolated fundamental.

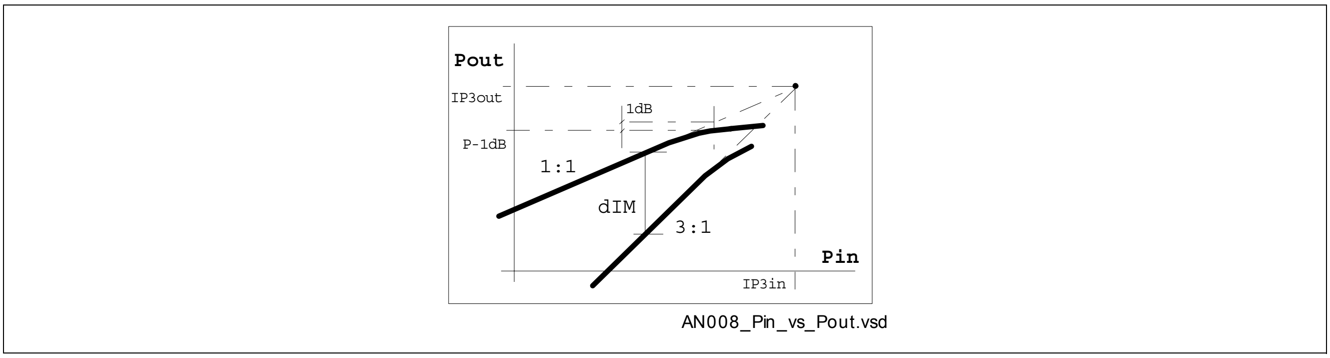

Figure 6 P_{in} versus P_{out}

The intercept point although measured at the output, can be refer to the input as well:

$IP_{3out} = P_{out} + \Delta IM/2$................. 3rd order intercept point at the output [dBm]

$IP_{3in} = P_{in} + \Delta IM/2$................. 3rd order intercept point at the input [dBm]

$IP_{3out} - IP_{3in} = \text{Gain} = P_{out} - P_{in}$

P_{out} and P_{in} are power levels of one fundamental. The dIM-value is the difference between the fundamental and the IM product in dB.

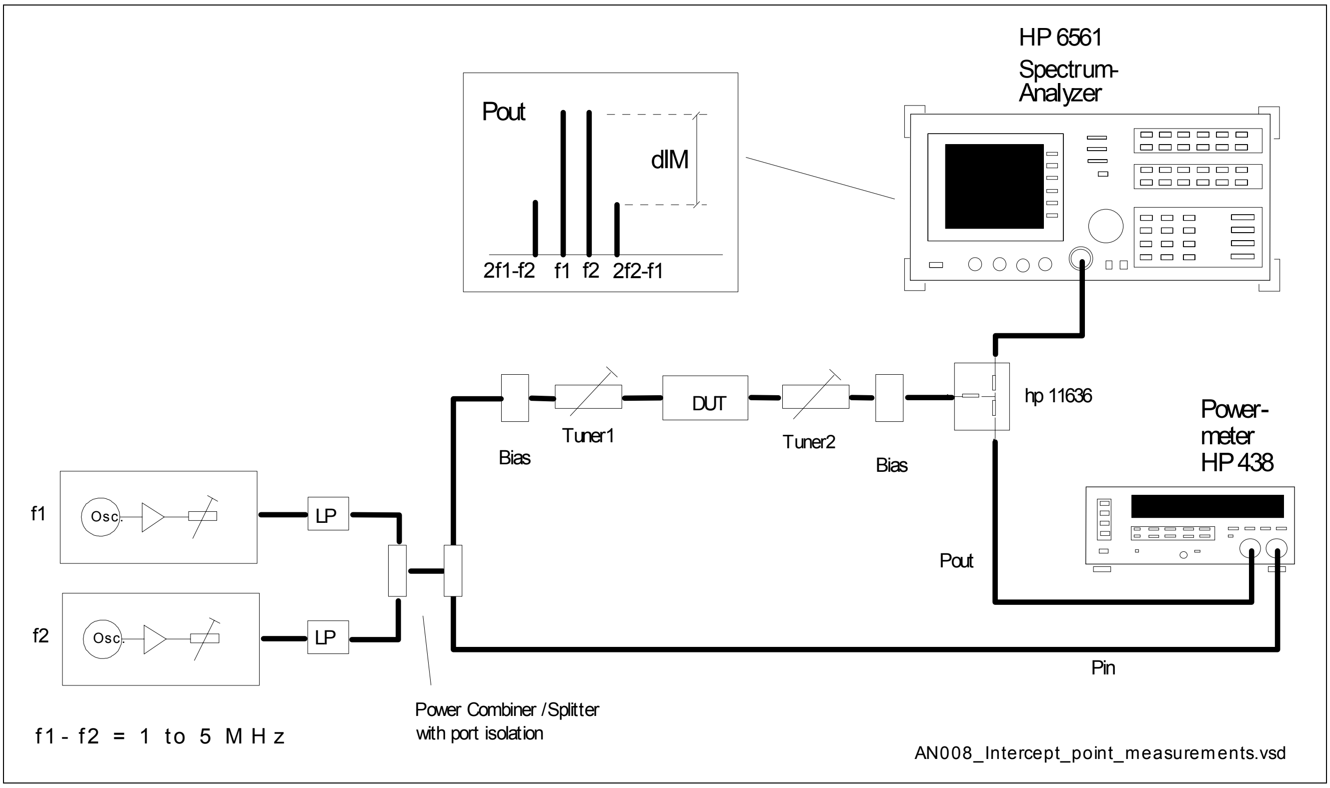

Figure 7 Measurement of Intercept point

The measurement is taken with relatively small signals in order to get ΔIM-values between 50 and 60 dB. The DUT can be matched for optimum IP_3 behavior or measured unmatched (50 Ω), which is more appropriate to broadband application. Losses between DUT and power meter have to be accurately taken into account.

Although the typical application of the above setup is the characterisation of amplifier transistors, it is useful with a mixer as DUT as well. In this case the spectrum analyzer has to be tuned to f1 - f_{LO}, but the level definitions are not affected.

The reading of the power-meter shows both carriers. For calculation of the IP_3 the power of only one carrier is needed (-3 dB).

1.5 References

1. R- Soares-GsAs-MessFET Circuit Design, Artech House, Inc., 1988
2. G. Gonzales: Microwave Transistor amplifiers - Analysis and Design, Prentice-Hall, Inc., 1984
3. G. Lohninger, J. Huber, “50 Ω auf dem Wafer messen,” ELEKTRONIK Heft 9/95, Seite 53-54.
4. Application Note HP 376-1