# Limitations and Recommendations in Noise Measurements

General Rule:

The Critical Sections in a tuner measurement setup are the sections between the RF Probe of the tuners and the DUT. The Reflection Factor and the Insertion Loss of these sections has to be minimized as far as possible.

Interferences: Noise measurements are very sensitive. The typical power detected at the receiver input is -110dBm per MHz bandwidth (or 0.022 micro volts/Hz at 50 Ohms). Interferences with external radio sources are therefore critical and will lead to false results. However this will normally happen in a random way, which makes their detection even more difficult.

It is therefore strongly recommended to check with a spectrum analyzer for spurious signals and use, if possible, a shielded test environment (Faraday cage, shielded test fixtures, power lines etc..).

A simple way to detect such parasitic effects is to repeat the same measurement several times and observe the dispersion, or make swept frequency measurements and look for peaks or ditches. The noise measurement system should reproduce the same result (within 0.1dB) of minimum noise figure.

Noise parameters of transistors are smooth functions of frequency . Swept noise parameter plots would immediately reveal anomalies in form of peaks or valleys. In this case you may have a local frequency problem, oscillation or so or external interference.

Receiver Noise Figure: After receiver noise calibration you should check the noise figure of the system with a Thru-Line inserted in the test fixture. All around the Smith Chart you should get ~0dB (corrected) noise figure. Deviations up to 0.2 dB are acceptable. This number increases slightly with frequency. If you don't then the setup is not properly calibrated. This may include the S-parameters of the blocks or the noise calibration itself. The calibration must be repeated.

The Recommended Receiver Sensitivity in form of the LNA Noise Figure is: NFrec<= NFdut +Gav. dut - 5 dB. Example: To measure a 1 dB noise figure of a transistor with ~10dB gain we should use an LNA with better than 6 dB noise figure. Since the gain of the DUT changes a lot with Ys it is recommenced to use lower noise receivers. Also it must be considered that the noise figure of the receiver "in operation" will be higher than its 50 Ohm value, since it will be seeing the output of the DUT as a source impedance.

Verification: Thebest verification of the Noise Measurement System can be done directly after the Receiver Noise Calibration. By placing a THRU line instead of a DUT and using the S-parameters of a THRU line (S11=S22=0, S21=S12=1) one should measure noise figures close to 0 dB all around the Smith Chart. Variations of +/- 0.1dB are possible close to the center and may rise up to 0.3-0.4dB at the edge of the Smith Chart. This is within expected accuracy of such a setup. However one should not attempt to compute the four noise parameters of a thru-line as some of the readings may produce "negative" noise figures (NF<1 or <0dB).

Selection of Source Impedances: Measurements should be made close to the optimum source impedance but not on circles around it. The source impedance pattern should be on circles around the center of the Smith Chart. Some points beyond the optimum and some towards the center. There are many possible patterns and options. You should refer to the related literature for more insight details.

Double Side band: If you measure using a diode mixer and local oscillator directly connected after the LNA then you are doing Double Side band Measurements (DSB). Because the source impedance is different at both side bands so will be the gain of the transistor and by consequence the noise power contribution at the output. This is a systematic error in the measurement and we do not know of a simple method to avoid this, except to compute the gain at the two side bands and warn the user for the difference. It is better to use a Single Side Band receiver (HP-8971) or a spectrum analyzer. Both include a YIG filter at the input which suppresses one side band's power (see AN-31).

Instability/mismatch factor/error correction: When you select a source impedance you may be close to the instability circles of the DUT. Not using an output tuner degrades somehow the sensitivity of the system (unmatched receiver) but stabilizes the DUT. WinNoise and other noise measurement softwares display the stability circles on the Smith Chart so, in general, you are aware on the situation. You will discover that you have to tune close to instability, in many cases. Nevertheless it is possible to avoid oscillations, especially with mechanical tuners that have 50 Ohm impedance at lower frequencies. When you are close to a stability circle then the impedance seen at the output of the DUT goes towards |S22=1|. In this case the effective noise figure of the receiver (to be corrected for) becomes high, and so becomes the possible correction error.

Gamma Max: It is recommended to place at least one or two source impedances close to the noise figure minimum and some, if possible at higher reflection. This will provide a better accuracy for the solution of the noise parameter equations. In order to do this we require a tuner with high Gamma Max and a low loss test fixture and cable connection to the tuner. The lower the reflection and the loss of this section the more confident the results will be.

Evaluation method: Focus is using the classic evaluation method of R.Lane first published in the 70ties. Some corrections are applied when the source impedance data are close to open circuit in order to improve numerical resolution, but otherwise the method itself is published in Application Note 19 (see in Literature section).