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PRACTICAL ASPECTS ON NOISE FIGURE MEASUREMENT

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Göteborg, jun 22-23th 2009

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Agenda:

- Room Temperature environment NF Measurement: **Transfer LNA**
- Cryogenic environment NF Measurement: **Faster cooldown**

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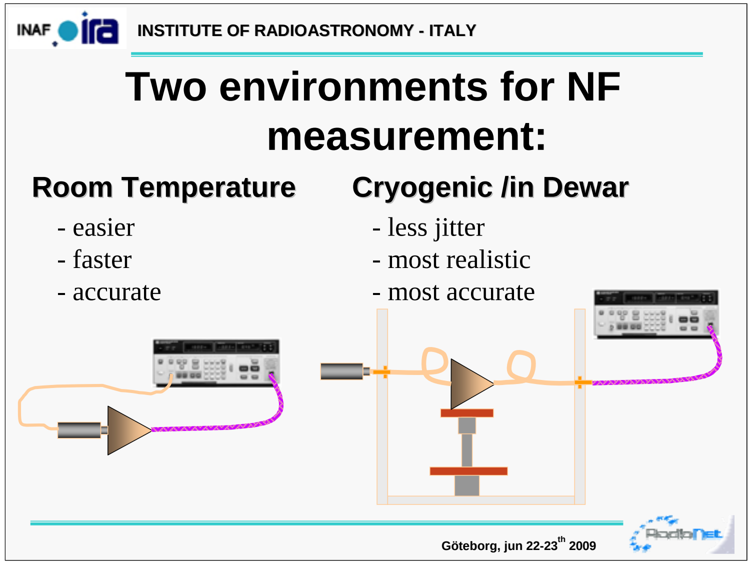
Two topics are presented.

The first, The Transfer LNA, may be an help in order to reduce differences in NF measurements.
It reveals differences in ENR vales and it’s applicable especially for room temperature measurements.

The second is a practical method to reduce the cool down time.

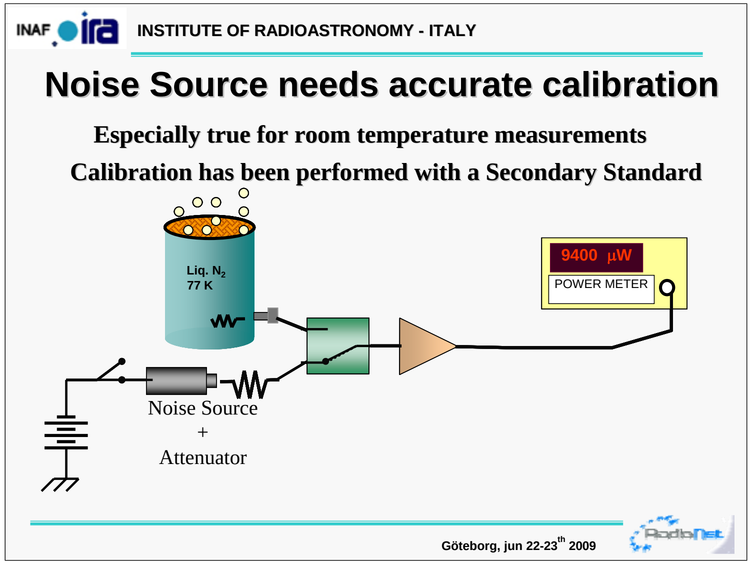


Two are the convenient environments where perform the Noise Figure (or Noise Temperature) measurement.

Room Temperature environment is easier and quicker than Cryogenic but it's more jittering and a bit less accurate (more sensitive to uncertainty of Tcold and ENR).

Cryogenic environment measurement using the cold attenuator is more accurate, but it need long time (slow cool down time).

This is one important reason because the room temperature environment NF or Te measurement still remain important.

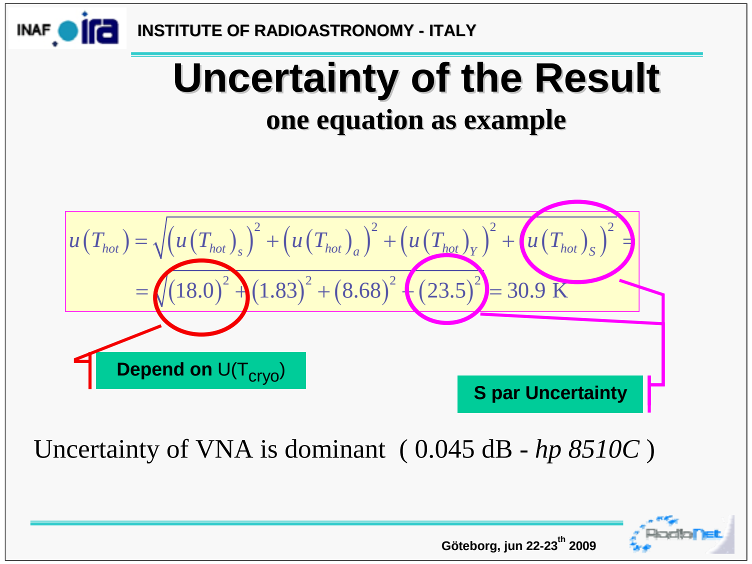


This is a sketch of the Noise Source calibration procedure.

For every frequency, the switching sequence has been repeated quickly and many times in order to reduce drift and produce a valid statistics.

The spar of every device and paht has been measured in the most accurate way.

A full coverage from 1 GHz to 18 GHz need 1 month-man of laboratory job and 1 month-man of post processing.



The overall uncertainty is the RSS of may terms.

Namely, the most significant are:

1) Noise Source - LNA mismatch uncertainty,

2) Noise Source ON – OFF mismatch differences,

3) Cold (room) temperature Uncertainty

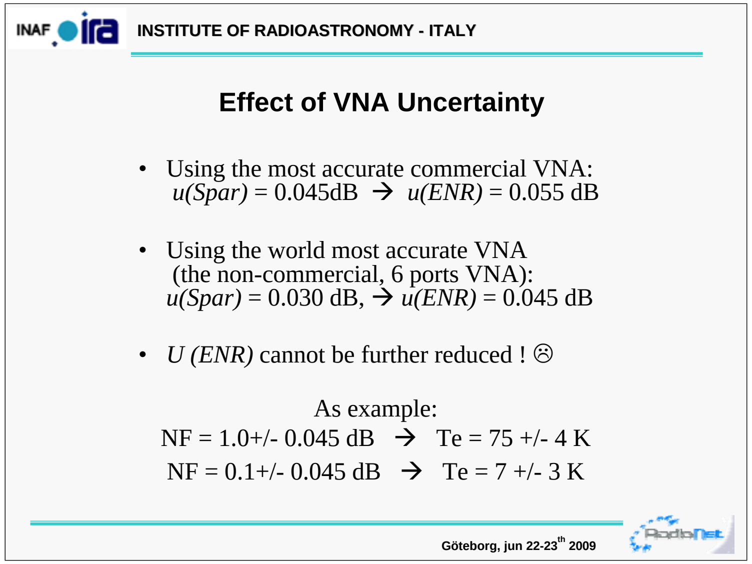
4) ENR Uncertainty

The first three can be minimized or taken in account, the 4th can be slightly reduced by long time cryo-load calibration.

As example, the equation of the Uncertainty of Thot (or ENR if You prefere) is shown.

As You may see, the most important contribution is due to the uncertainty of spar of the path between LNA and cryo load; it depends on VNA uncertainty (si ma non solo tra LNA e cryo load , anche dopo il carico)

Following , slightly lower, the contribution due to spar measurement of the cryo load, once again it's dominated by VNA uncertainty (che intendi i par S della transizione dopo il carico) .



As it can be seen, the uncertainty of ENR (Th) is mainly dominated by the uncertainty of the spar measurement.

Practically, u(ENR) cannot be reduced strongly down to +/-0.05dB

Is +/-0.05 dB a small or big value? When we measure cryo LNA with Te<10K , the residual uncertainty , even if 0.05dB only, may produce a uncertainty band as wide as the value !

When the uncertainty cannot be reduced….

….the only way is the comparison

(as the metrological laboratories do)

A transfer standard may travel around the radioastronomical laboratories in order to compare NF or Te measurements ☺ .

Unfortunately the NF or Te standard do not exists ☹.

Once all causes of uncertainty are minimized , the only possible way is a comparison (not a competition) between laboratories.

Governative laboratories periodically compares their standards by travelling secondary standards, while IEEE-ARFTG proposed a travelling DUT rather than a travelling standard.

Why a transfer LNA isn't a standard?

Because measuring an LNA using a physical standard is a correct operation, while try to calibrate a standard using an LNA is a mistake.

The NF or Te of an LNA depends on it's intrinsic properties but even on Temperature, aging, bias supply, etc.

Since an Input Noise Temperature Transfer Standard do not exist (because an LNA isn't a standard since its noise depend on many variables), the only practical way is a comparison of a travelling DUT (travelling LNA).

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But in the practical way…

Under certain conditions, as a precise, detailed operative procedure, the LNA acts as a Transfer DUT.

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The LNA acts as a Transfer LNA only (and if only) the operating procedure will be respected rigorously by very skilled worker.

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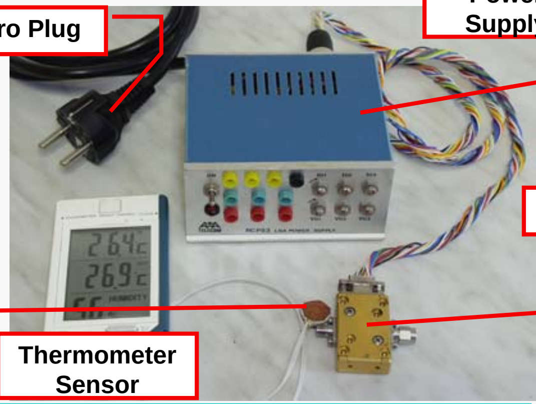
The TRANSFER LNA



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The transfer LNA will be shipped into a cardboard box.

It’s as plug’n play as possible.

Not shown here , the ferrite circulator.

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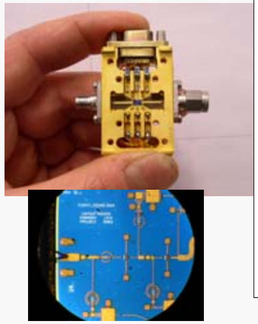
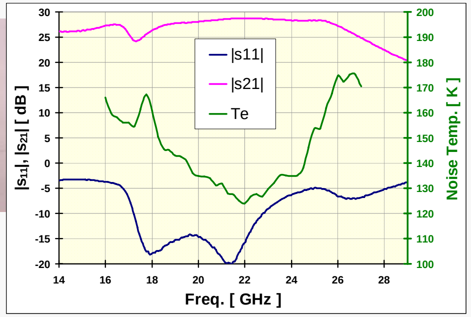
Inside the Transfer LNA





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Some details of the LNA

In-P, MMIC based, it operate from 16 to 26.6 GHz,

The Gain (27 dB) is high enough to mask the Input Noise of Noise Figure Analyzer.

The Input Noise Temperature at 27°C has been measured at INAF-IRA lab., it spans from 125K to 175K .

The power supply is a copy of the well known, NRAO designed, constant current.

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To do

- Every lab should performs a room temperature measurement of the Transfer LNA using its own noise generator.
- Then, sends back the LNA and the measurement data files.

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Why coax 16…26 GHz ?

- Coax media has been chosen because more friendly and broadband than waveguide.
- Coax Cryo Noise Standard are limited up to 18 GHz.
- Almost all laboratories can operate, at least, up to the popular 18 GHz boundary.
- The 16…26 GHz bandwidth is a choice: it breaks the 18 GHz boundary building a continuum with the Ka Band while, in the same way, give the freedom to produce a measurement limited to 18 GHz.

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Why the thermometer ?

- Physical temperature strongly changes the NF or Te of the LNA
- Physical temperature strongly changes the Toff of the Noise Source
- Physical temperature need to be known and to be stable over time.
- Firmly join, and make it isothermal, the end part of Noise Source and the LNA

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The operator should place the thermometer sensor in thermal contact to the end part of the Noise Source and the Input of the transfer LNA.

Once the thermalizzation process is finished (at least 15 minutes) the read physical temperature should be placed into NFA (hp 8970, Eaton-Maury, homemade) or compared to the one read by instrument (Agilent N897xx) . Also the temperature read by the thermometer should be enclosed with other data and sent to me by email.

Why (or why not) the Ferrite Isolator ?

- The LNA alone is well matched at center band and not at boundaries.
- A set of two measurements (with and without the isolator) made with the same Noise Source - if compared to the measurements made from other labs - point out if differences are due to ENR or Noise Source mismatch

Every laboratory is invited to perform at least two set of measurement:

One without an input isolator, and one with the input ferrite isolator.

Differences in the values are natural but difference in the pattern form (especially the ripple) help us to find a probable cause of uncertainty: the mismatch rather than difference of ENR

Operations are the simpler as possible, but a skilled operator is needed

…the best is a maniacal – obsessive operator

- Open the cardboard box
- Connect the LNA to power supply and screw it to NFA.
- Wait 10 min. for thermalizzation after screwing.
- No direct sunlight, nor heater or air conditioner.
- Take in account the temperature read on the thermometer.
- Perform measurements with and without ferrite isolator.
- Check NFA calibration at the beginning and the end.
- Send files by email.
- Return the LNA ad Power Supply in the same box.

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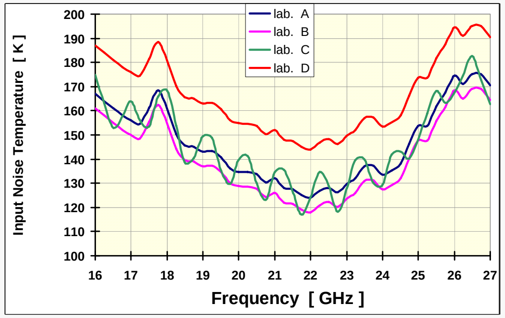
What I'm expecting



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The lab. A is basically the same of the lab. B

The lab. C has basically the same average value of A and B but more ripply.

The lab. D is very different from the average of the previously three measurements.

Possible facts:

Lab C has poor Noise Source Reflection Coefficient

Lab D has a real ENR lower than the nominal one.

Possible actions:

Freedom to take any possible actions.

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Do You like the idea?

Register yourself now, and tell me the name and contact of the person that will do the measurement.

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2° PART
How to make quicker the cooldown

- The cool down time for an LNA into laboratory Dewar takes many of the daily work-hours, usually one or two work-days are needed in order to perform the necessary measurements.
- When the quantity of LNA is large (an array) , the requested time became weeks or months.
- A method is presented in order to reduce the cool down time

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On the other hand, the 2nd part of the talk is relative to improve the cryo measurement by the reduction of the cool down time.

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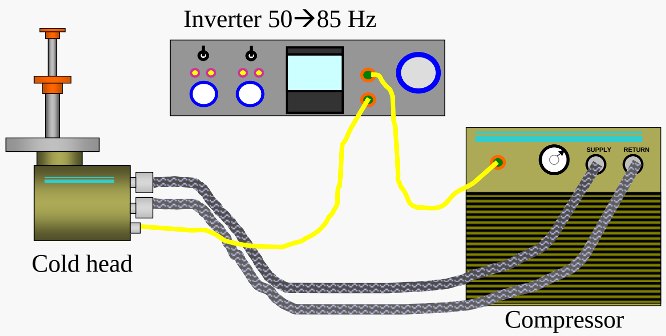
Phase A
An inverter is used to speed-up the cryocooler



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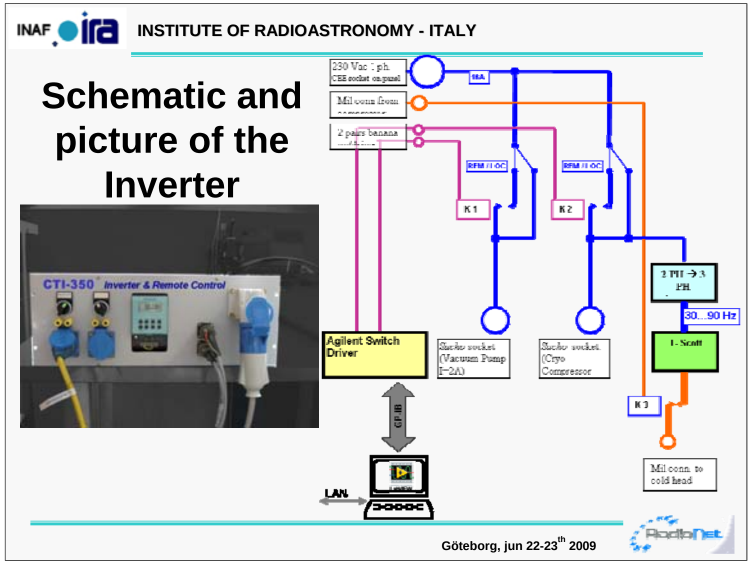
The way to speed up the cool down time is to speed up the cold head.

What does happen if we drive the cold head with an higher frequency?

As all electric motors do, it run quickly.

Does the cooling capacity increase?

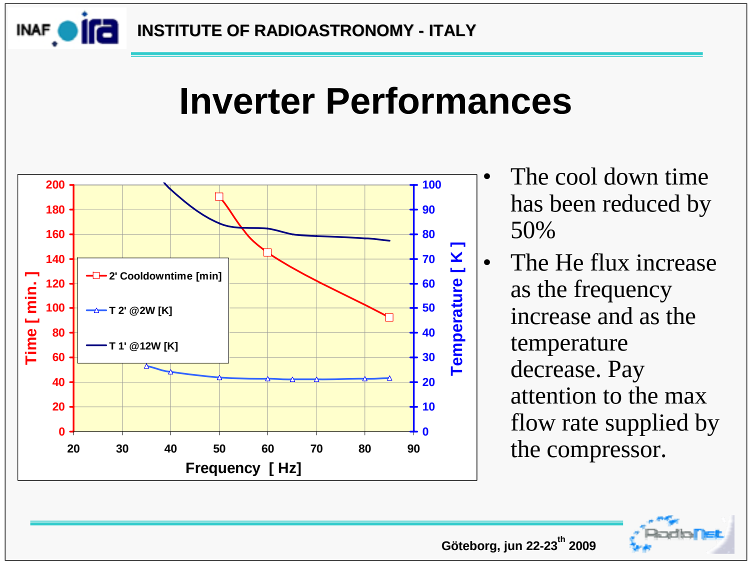
The correct answer is “it depends ! “ , In some case and circumstances : YES IT DOES !



The inverter unit do more than frequency variation.

In a basic description I may summarize:

1) Frequency inverter , Out frequency up to 90 Hz (over than 90 Hz the motor resonate itself)
2) A T-Scott transformer in order to generate two perfectly quadrature power lines.
   The perfect quadrature, rather than the capacitor, reduce strongly the vibrations and audible noise.
3) Remote Control. By the use of relais and an “old” Agilent Switch Driver the unit can be remote controlled by a software and/or the LAN.



The graphics shows the performances in the (mains) frequency domain.

While there’s no significant differences in the final temperature (blue curves) , the cool down time is reduced by a factor 2 when the mains frequency is increased from 50 Hz to 85 Hz.

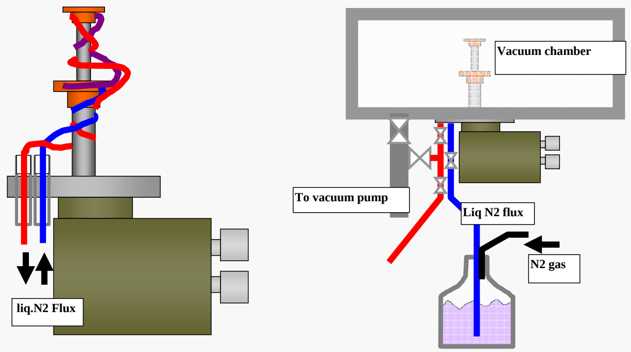
Note on Helium flow rate:

The compressor supply a limited He flow rate. The cold head need a He flow rate proportional to the frequency of expansions and inversely proportional to the temperature. At the finale temperature the frequency must be reduced to 50…60 Hz because the limited flow rate of the compressor.

Phase B
pre-cooling by liquid Nitrogen
(at present it's only a design)

- Use the le liquid Nitrogen for the pre-cooling of the LNA.
- A thin stainless steel pipe line is wrapped around the two stages of the cold head.
- The liq.N2, flowing inside the pipe line cool down both two stages of cold head in a dry / vacuum environment.

Principle of Operation



A thin stainless steel pipe is wrapped around the two stages.

Normally the pipeline acts as thermal isolator , but when the liq. N2 flows into the pipeline the heat will be quickly exchanged and transported away by the liquid nitrogen.

The operator may decide if use or not this facility. Even if installed, it's use isn't mandatory.

Firstly the liq.N2 will be flowing into the pipeline until the stages will reach 80K or less, then the pipeline will be isolated and evacuated by a vacuum pump in order to prevent air condensation and ice inside the pipe.

The cryogenerator will continue the cool down up to 20K or less.

Of course, while we work with cryogenic liquids, the safety became a fundamental task. Lots of relief valves are needed in order to prevent risks.

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Conclusions

- An inter - laboratory comparison of methods and Instruments to measure NF or Te at room temperature is suggested.
  To do the comparison, a transfer LNA may travel around laboratories.
- A method to speed up the cool down time of cryogenerators is presented, an electronic inverter may reduce the time from 3 to 1.5 h, and if boosted by liq. Nitrogen the cool down time time drop to 30 min.

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Acknowledgements

•Thanks to Marco De Dominicis for his precious suggestions and critics.

References

•[1] Marco De Dominicis, ***"Strumentazione e Metodologie per la Modellistica di Rumore di Dispositivi Attivi ad Alta Frequenza"***, PhD Thesis , University of Roma 2, 2004

• [2] Sergio Mariotti et al., "***Reduction of the Uncertainty on Noise Figure Measurements*** ", RadioNet Meeting Onsala 2006.

•[3] IEEE-ARFTG, ***"S-Parameter Measurement Comparison"*** http://www.arftg.org/s_parameter_meas.html

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Thanks for Your attention

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