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# **NOISE SOURCES COMPARITION**

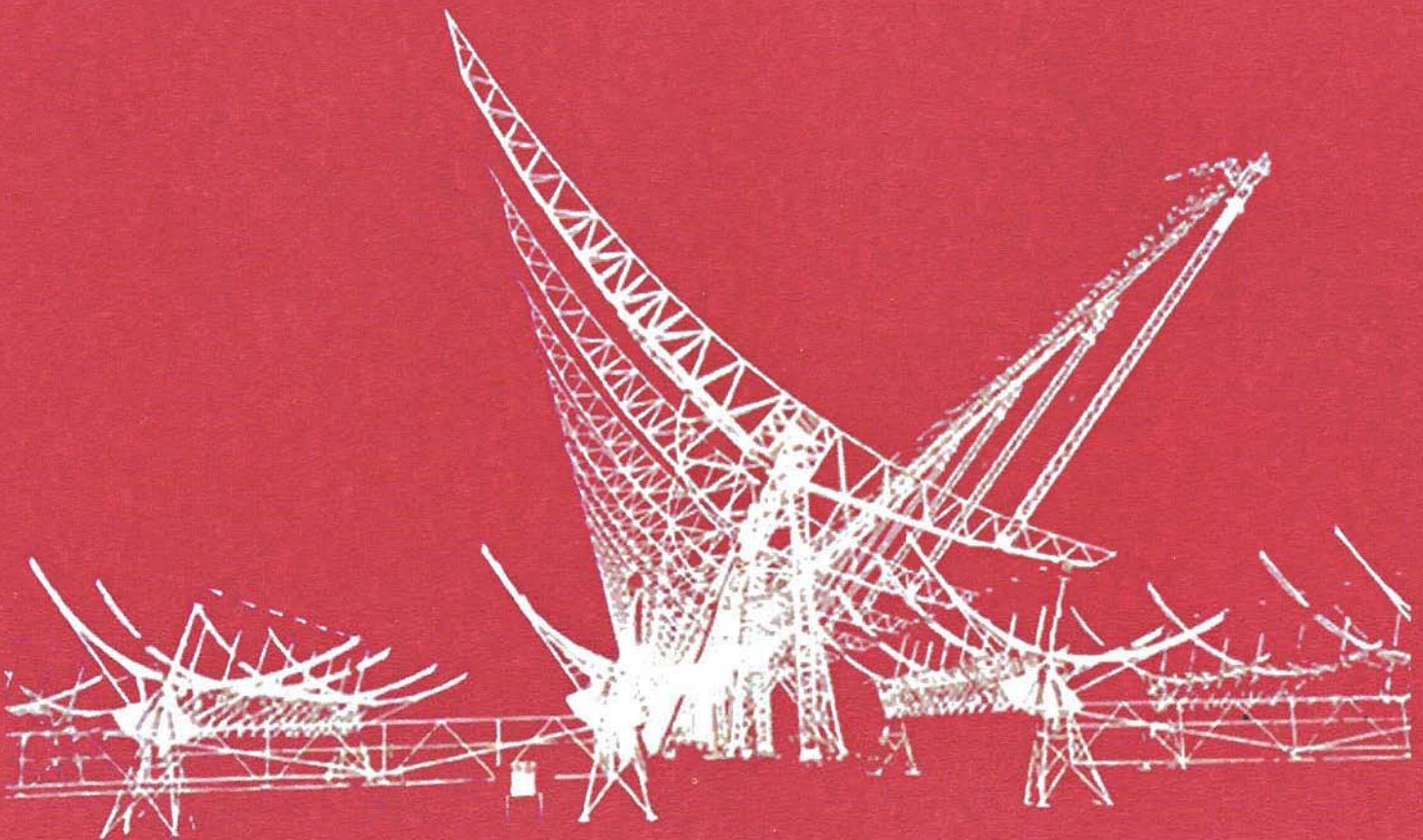
## **AROUND THE EUROPE**



*Sergio Mariotti*

RAPPORTO INTERNO IRA N° **439** / 2010

# RAPPORTO TECNICO



## Noise source calibration with a travelling amplifier

**Background:** The overall uncertainty in Noise Figure measurements is dominated by the uncertainty in the amount of noise generated by the noise source (Excess Noise Ratio ENR and uncertainty of the ENR). For more than 30 years the most accurate noise generators in the market had an uncertainty +/- 0.12 dB. Leading brands were: Noise/Com , HP/Agilent, Micronetics.

In 2003 work between INAF-IRA and Uni. Rome Tor Vergata (UTV) reduced the uncertainty to +/-0.06 dB at frequencies up to 26.5 GHz. A theoretical study between INAF-IRA and UTV showed that the uncertainty cannot be less than 0.055 dB. Note that an uncertainty of the ENR of +/- 0.055dB becomes an uncertainty of  $\approx 0.09$  dB on the noise figure i.e.  $\approx 7$ K at ambient temperature. In 2004 Agilent offered a very accurate noise generator ( +/-0.06 dB up to 18 GHz).

**Comparison of the most accurate noise sources around the Europe:** the comparison of the most accurate noise generators cannot further improve the intrinsic accuracy. But a comparison campaign will reveal if each laboratory is inside or outside the uncertainty boundaries. Measurements closer to the overall mean build trust for that particular noise generator and test system. Conversely measurements far from the mean indicate that corrective action (such re-calibration) may be necessary.

**Organisation of the job:** each contributing Institute /Laboratory have performed the measurement of a travelling LNA using their own noise source and related instruments. The measurement has being performed in the most accurate and precise way at room temperature for simplicity in this phase of the test programme. Each Institute has sent the data file to INAF-IRA for the comparison. The project is started in July 2009 and finished in September 2010.

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<i>others labs in the future?</i>	

# NOISE SOURCES COMPARISON AROUND THE EUROPE

## *FINAL REPORT*

### INTRODUCTION

It's well known that the correct way to furnish an experimental measure is to provide both the observed value and its associated uncertainty.

For the low noise amplifiers, the improvement of the technology and the cryogenic cooling has produced a decreasing of the input Noise Temperature down to few times the theoretical quantum limit  $h\nu/k$ , while the associated uncertainty isn't affected by any reduction.

It isn't rare a case we quote the noise temperature of an LNA as  $T_e = 10 \pm 20$  K.

The causes that generates and propagates the Uncertainty are well described and discussed in [1] and [2].

Here's a summary of that causes and typical values for the travelling LNA (described later) measured by a typical mod. 346C Noise Source [3]

	[ dB ]
Uncertainty related to the LNA Noise Figure [strongly dependent on U(ENR)]	0.20
Uncertainty related to Instrument Noise Figure	0.004
Uncertainty related to LNA Gain Measurement	0.01
Uncertainty related to ENR	0.15
<b>Overall (RSS) Uncertainty on Noise Figure (1 <math>\sigma</math>)</b>	<b>0.25</b>

In this case, the NF of the LNA is  $NF = 1.7$  dB  $\pm 0.25$  dB or  $139 \pm 26$  K (  $1\sigma$  ).

It's evident that the strongest cause of U( $T_e$ ) is the U(ENR).

The most obvious questions is how the U(ENR) can be reduced?

Before to answer, it's necessary give the answer to another question: What is the minimum theoretical limit of U(ENR) ?

The answer may be found in [4] and in [5], and may be summarised as follow:

ENR is determined by the help of a radiometric chain. At the input a relays switch sequentially three arms of the chain, the cold standard, the hot standard and the unknown noise source.

U(ENR) is the resultant propagation of many causes of uncertainty but the most significant are:

The uncertainty of the temperature of the cold noise source U( $T_{cold}$ )

The uncertainty of the spar of the arms of radiometric chain used for comparison U( $s_{ij}$ ).



Given the most accurate data values obtainable from a commercial Network Analyzer and a Standard Cold Load, both operated by a very skilled operator, a Noise Generator may be calibrated with  $U(ENR) = \pm 0.055 \text{ dB}$  ( $1 \sigma$ ) at 18 GHz.

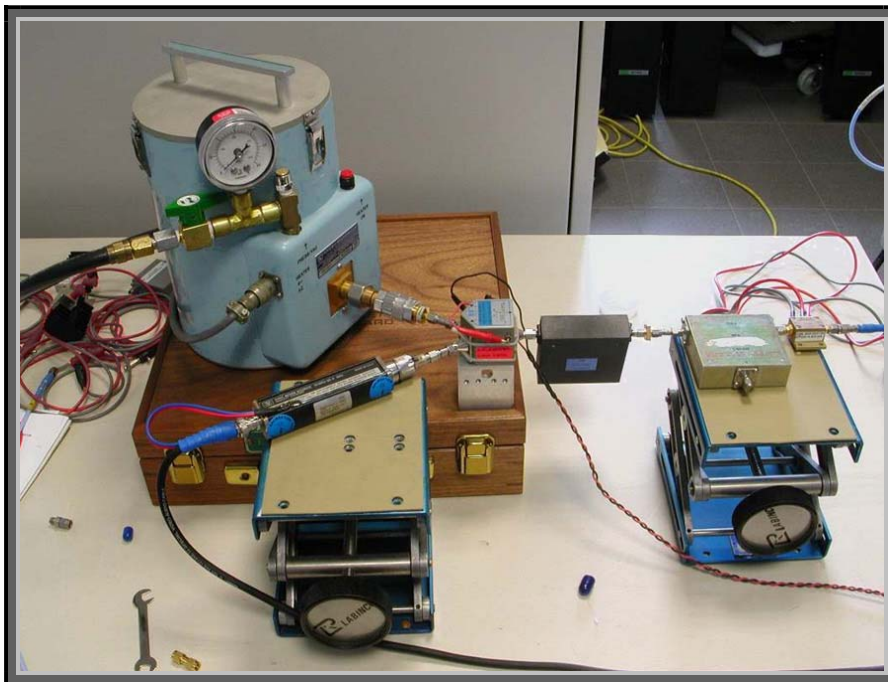
For more than 20 years, the most accurate Noise Generators sold by hp/Agilent, the mod. HP346, had  $U(ENR)$  quoted  $\pm 0.15 \text{ dB}$  ( $1 \sigma$ ). In the hp/Agilent documents, for the mod. HP346 has been wrote that:

the vector method to reduce the  $U(ENR)$  was known but not applied [6]

the uncertainty was quoted at  $1 \sigma$  instead the more common adopted value  $2 \sigma$  [7].

In Year 2003, a join workgroup of INAF-Institute of Radioastronomy and University of Tor Vergata has lowered the uncertainty of their own Noise Generators by application of the most accurate vector method known [5]. The estimated uncertainty reached was:

$U(ENR) = \pm 0.055 \text{ dB}$  ( $1 \sigma$ ) at 18 GHz.



**1 In house Noise Source calibration with secondary standard**

In year 2004 Agilent started to sell a more accurate Noise Generator, the model series SNS N400x, the related Uncertainty was quoted:  $U(ENR) = \pm 0.06 \text{ dB}$  ( $1\sigma$ ).

Despite of the uncertainty has been strongly reduced and the theoretical limit has been almost reached, the value of  $0.055 \text{ dB}$  cannot be considered a “small” value. Note that realistically, a  $U(ENR) = 0.055 \text{ dB}$  once propagated, produces a  $U(NF) = 0.09 \text{ dB}$  ( $\pm 7 \text{ K}$  at  $1 \sigma$  or  $\pm 14 \text{ K}$  at  $2 \sigma$ ) [3].

What action can be taken in order to further improve the uncertainty?

As suggested by [8] and [9] the only possible action is a comparison. The inter-laboratory comparison by itself doesn't further reduces the uncertainty but it enhances the differences and should suggest some corrective actions, especially for the values farther from the mean.

## COMPARISON

The inter-laboratory comparison is not a re-calibration. By itself doesn't change the ENR of the compared Noise Sources. The differences in readings occurring at each laboratory will not be cleared.

Only once this document has been read, each laboratory will have the freedom to apply corrections to ENR. In any case, each correction should be applied with great precaution and cautiousness.

The canonical way to do a comparison is a comparison of a travelling standard. An Input Noise Temperature Standard ( an LNA with a standard Noise Temperature) doesn't exist.  $T_e$  of LNA is every time dependent on ambient temperature , bias supply and even on the reflection coefficient of the source. But if the travelling LNA will be measured at known ambient temperature, biased by a very stable power supply and close on well matched load , its  $T_e$  can be considerate stable enough around the travel.

The comparison is more accurate as smaller is  $T_e$  of the LNA. So a cryogenic comparison, in principle, should be preferred to a room temperature comparison [10]. But practically speaking, a balancing of the Pros & Cons must be done:

	<b>Cryo comparison</b>	<b>LNA</b>	<b>Room temperature LNA comparison</b>
Man power required	week (s) (-)		hours (+)
Accuracy	best (+)		high (...)
Sensitivity to how the setup is arranged	more (-)		less (+)
Sensitivity to U(ENR)	less (+)		more (-)
Easy to do	less (-)		more (+)
Probability to find candidate laboratories	less (-)		more (+)

Due to that reasons, a room temperature comparison has been preferred.

### **Frequencies:**







Often the frequency boundaries comes at 18 GHz, 26.5 GHz, 40 GHz, 50 GHz, 67 GHz ...

The best seller Noise Generators covers the very popular bandwidth 10 MHz-18 GHz.

Of course, higher frequencies are also very important for radio astronomy.

It has been chosen a frequency range 16...26.5 GHz for the following reasons:

- The high end of the bandwidth (say 18 or 26.5GHz) is probably affected by greater uncertainty or errors than the low end of the bandwidth . A comparison is probably more meaningful at the high end of the bandwidth.
- 16...26.5GHz has been chosen because step over the 18 GHz boundary. In this way, even the laboratories that are arranged up to 18 GHz may takes advantage of the comparison.

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			Author: Sergio Mariotti	Revised by: A. Orfei, J.D. Gallego	Date: Oct. 9 <sup>th</sup> 2010

### Reflection coefficient and impedance matching:

The LNA has been impedance matched as well as possible, but it cannot be regarded as a well matched device.

As higher is the product of the reflection coefficient ( $\rho_{NS} * \rho_{LNA}$ ) as higher is the ripple of the  $T_e$  curve over frequency.

Two measurements are requested to the laboratories, one placing a selected low VSWR, ferrite circulator in front of the LNA and the other one without that circulator. All the measurements made with the circulator will be compared all together, as well as the measurements performed without the circulator.

Comparing the two obtained measurement traces, it's possible distinguish if the ripple is mainly due to mismatch errors or due to ENR differences.

### Drift:

Since a drift on gain and noise temperature may occur during the measurement session, a measurement of the "thru" is requested both at the beginning and at the ending of the measurement session. If an important drift will be seen, the  $T_e$  data file will be corrected.







### Room temperature:

The handling of the Noise Source and LNA as well as the solar light coming trough a window, as well as the vicinity of an heater or air conditioning changes the physical temperature of the LNA and consequently it's  $T_e$ .

For this reason a proper shield form heat/cold sources is required, as well a period of time long enough to reach the thermal equilibrium ( 5 minutes).

### Aging check:

At INAF-IRA the LNA has been measured both at the beginning and one year later at the end of the campaign. Differences on  $T_e$  was smaller than +/- 2 K except for frequencies greater than 26.3 GHz where the difference was slowly increasing with the frequency up to 10K.

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## DATA PROCESSING

The data files coming from each one laboratory have been analyzed.

Not all data set are organized on the requested way.

Some data are 50 MHz spaced while other are 100 MHz spaced. One data set is 500 MHz spaced.

This difference has involved a small complication on the processing but does not affects the comparison.

Most data set contains Noise Temperature and Insertion Gain while two data set contains NF (dB) only. This small lack does not affect the comparison.

Some data set do not include the “initial” and “final” zero traces. It has been assumed that the drift was negligible.

Where possible , the drift has been evaluated. For all data set both the Noise and Gain drifts were negligible.

Since the data set have been collected at different physical temperatures, a correction has been applied in order to normalize the actual Noise Temperature. The experimental found law

$$\frac{\Delta T_e}{\Delta T_{amb}} = +0.5 \text{ K}/^\circ\text{C} \text{ has been applied.}$$

Two families of Cartesian graphic have been plotted: the case without input isolator (NO\_CIRCULATOR) and the case with the isolator in front of the LNA (YES\_CIRCULATOR).

As it may be seen , the spread is very large. Also it’s difficult to understand the whole traces.

A selective analysis is much more indicative. Three kind of analysis has been performed:

- The effect of the mismatch loss is analyzed and discussed.
- the actual Noise Temperature trace is compared to the mean value (calculated at every frequency along the points coming from each Noise Generator).
- Traces performing similar behaviour has been looked for , grouped, analyzed and discussed.

### **What kind of mean?**

The most known method to estimate the mean value of a number of samples is the calculation of the arithmetic average, accomplished by +/- the standard deviation.

An alternative method, widely used at NIST, is the computation of the median accomplished by +/- the MAD [11] . For uniformly and normal distributed samples, the average and median are coincident, as well as the standard deviation and the MAD.

But in the case that few samples fall far outside the distribution law, the median better filters away the farther samples. Even the MAD, rather than the standard deviation, better filters the rare and farther samples. So the median method is more robust than the average one.

## RESULTS

### Impedance Mismatch effects

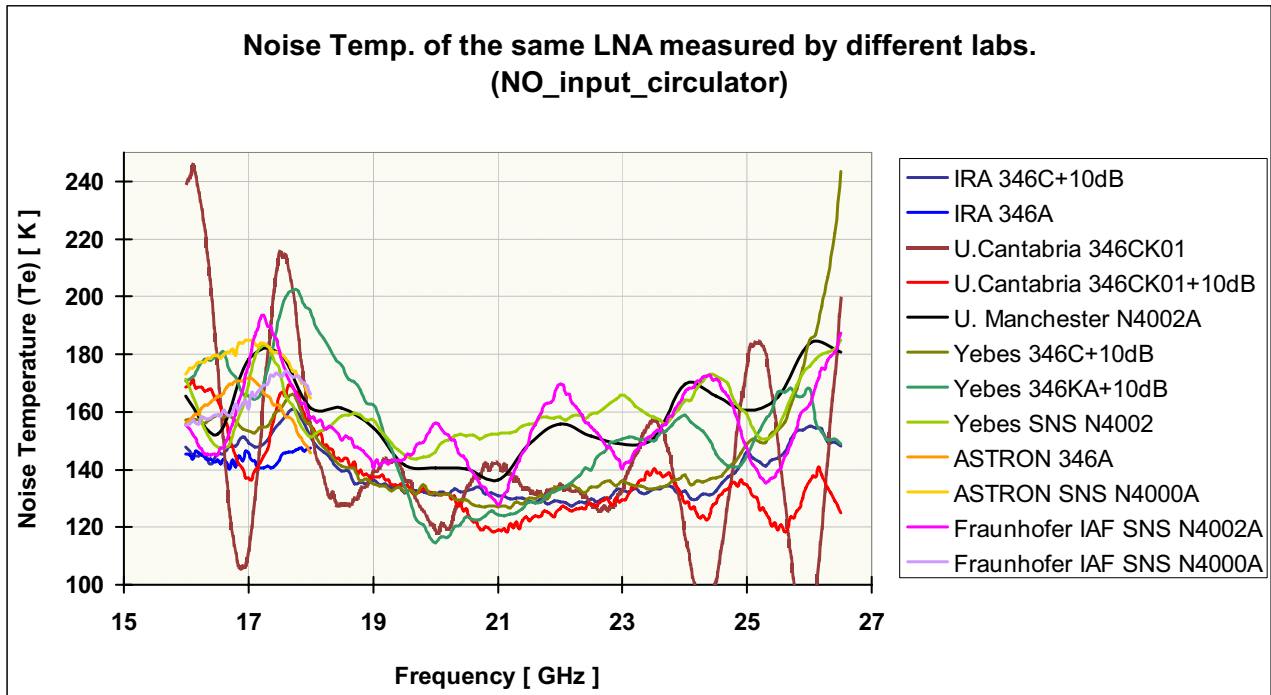
A mismatch error should generate a ripple on the frequency domain representation of the trace. The mismatch error is as large as the trace NO\_CIRCULATOR shows more ripple than the trace YES\_CIRCULATOR.

The mismatch effect has been summarized on the next table:

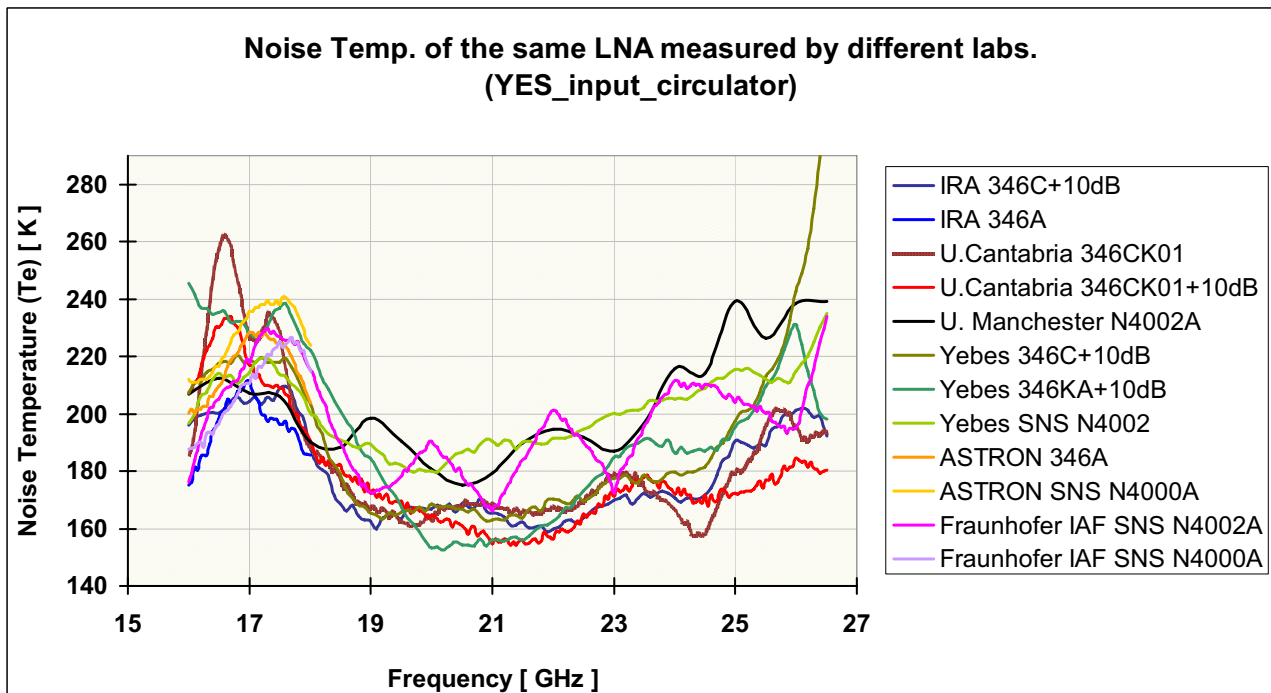
ORGANISATION	NOISE GENERATOR	Mismatch error (difference on the ripple)	Freq. range
Uni Cantabria	HP 346C K01	strong	16-26.5
Uni Cantabria	HP 346C K01+10 dB	absent	16-26.5
INAF-IRA	HP 346C +10 dB	absent	16-26.5
INAF-IRA	HP 346A	n/a	16-18
Uni Manchester	SNS N4002	small	16-26.5
Yebes	HP 346C+10dB	absent	16-26.5
Yebes	NC 346KA+10dB	absent	16-26.5
Yebes	SNS N4002	small	16-26.5
Astron	HP 346A	n/a	16-18
Astron	SNS N4000	n/a	16-18
Fraunhofer IAF	SNS N4000	n/a	16-18
Fraunhofer IAF	SNS N4002	absent	16-26.5



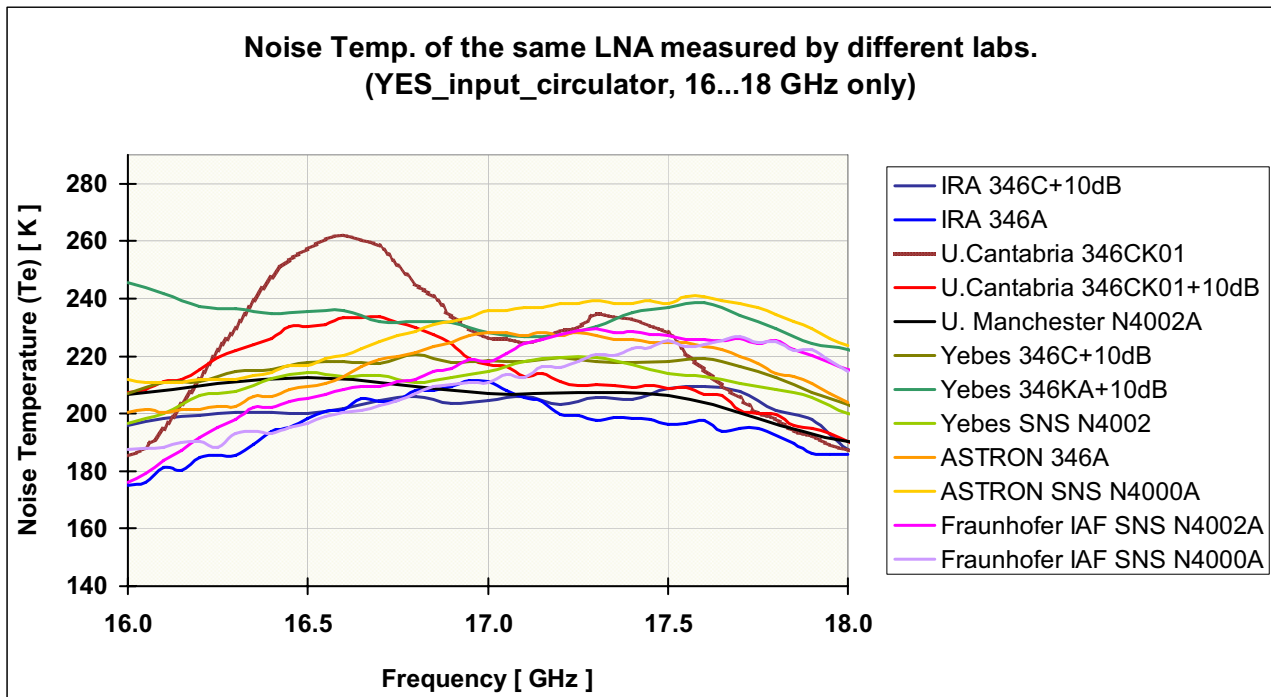
### Charts



2 Noise Temperature of same LNA measured by different labs ( NO\_input\_circulator)



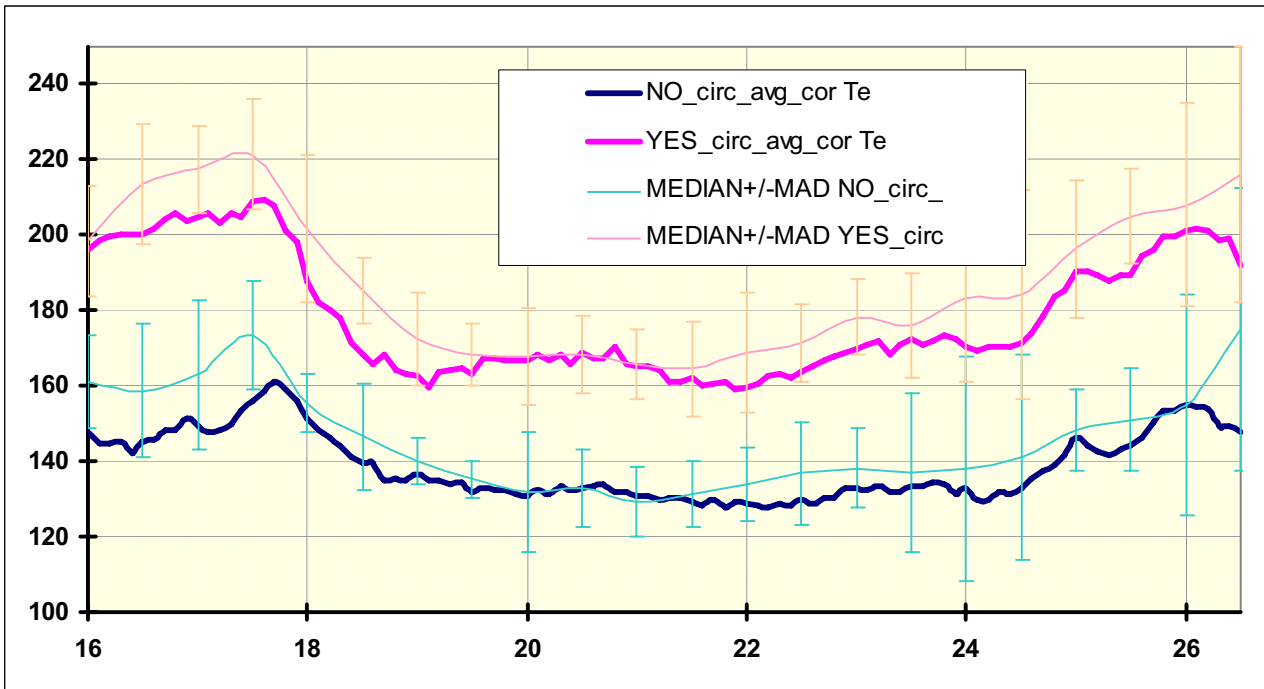
3 Noise Temperature of same LNA measured by different labs ( YES\_input\_circulator)



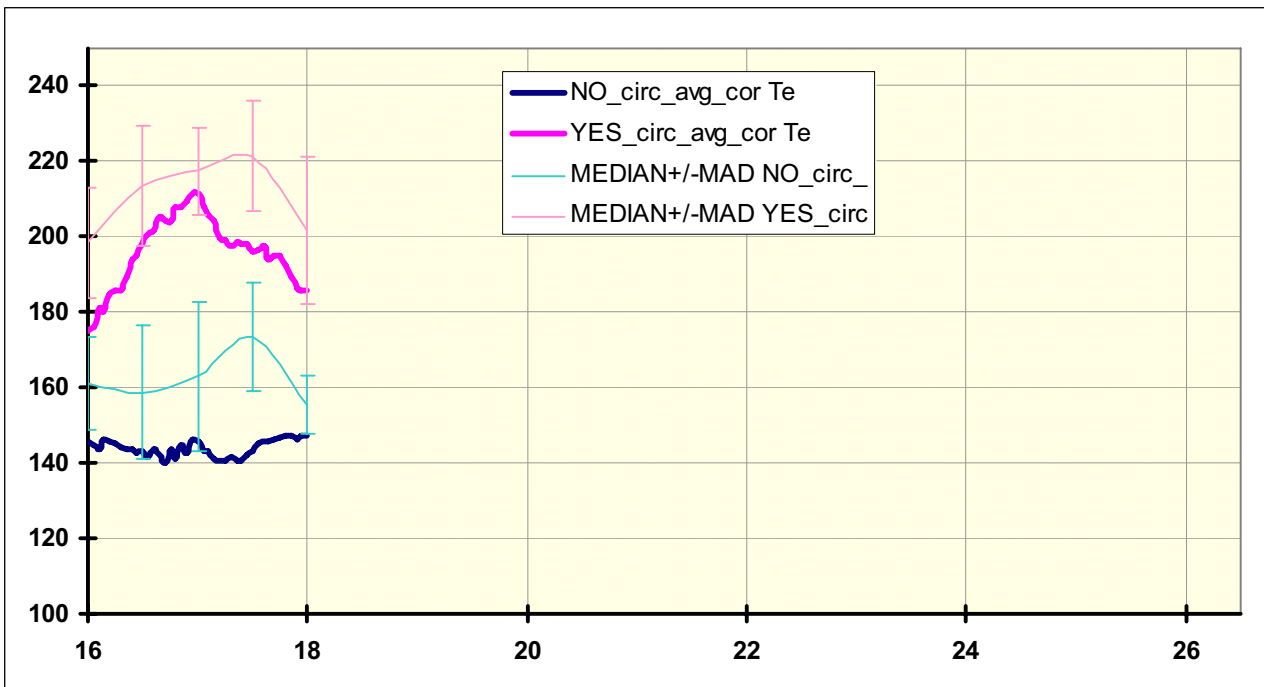
4 Noise Temperature of same LNA measured by different labs ( YES\_input\_circulator, 16...18 GHz only)

Even if the different colours may help the trace identification, the whole traces are not the best way to compare different measures because is confusing.

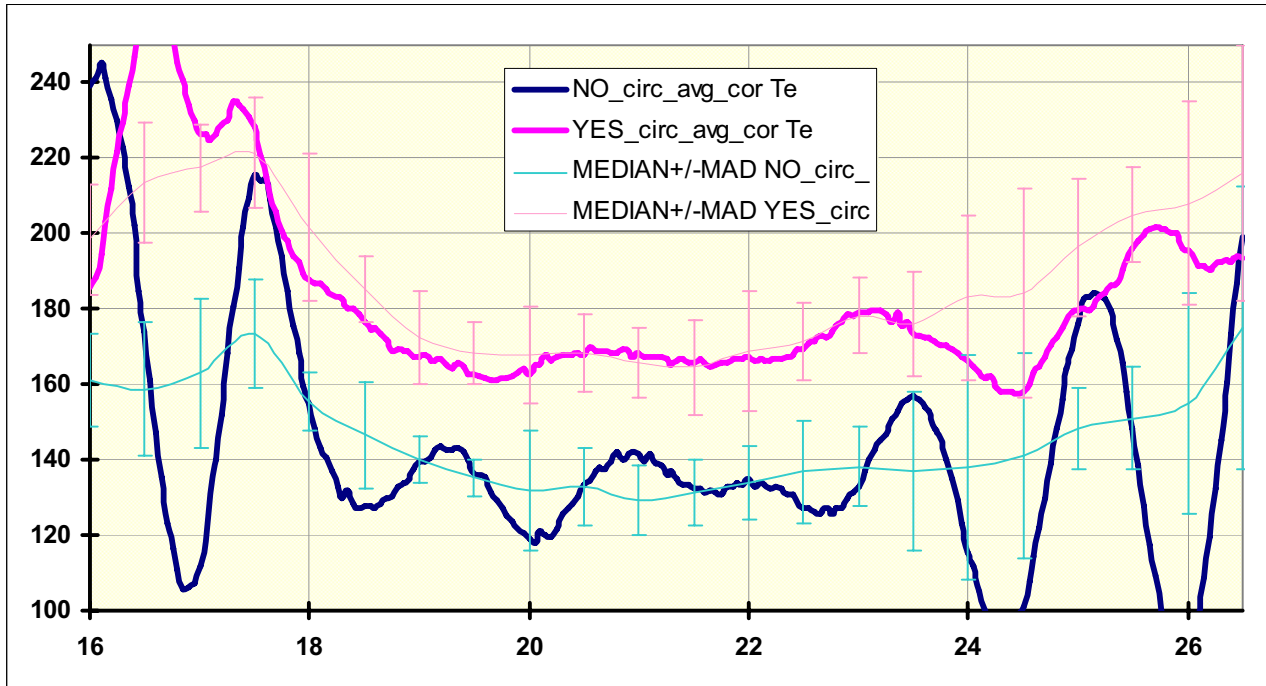
A good way to compare each measurement is a plot of every measurement compared with the “mean” of the measurements. As discussed before, the median value, rather the average , better describe the “most probable mean”.



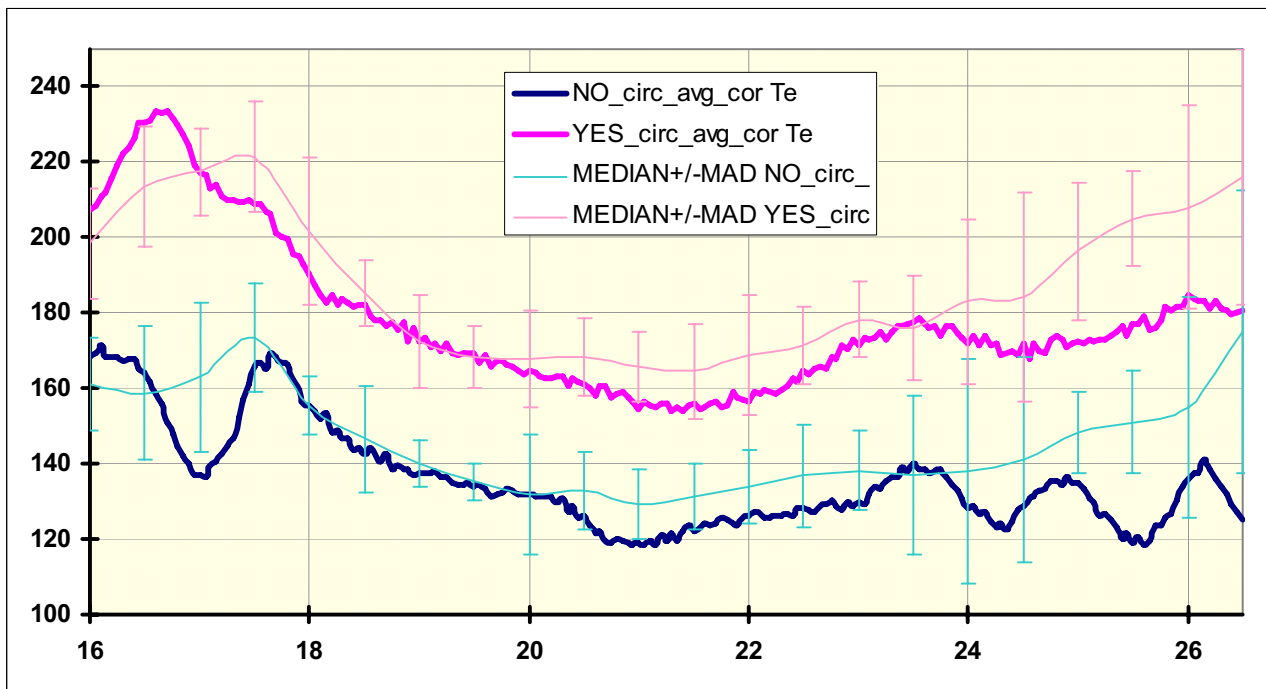
5 INAF-IRA , HP 346C+10 dB attenuator



6 INAF-IRA , HP346A

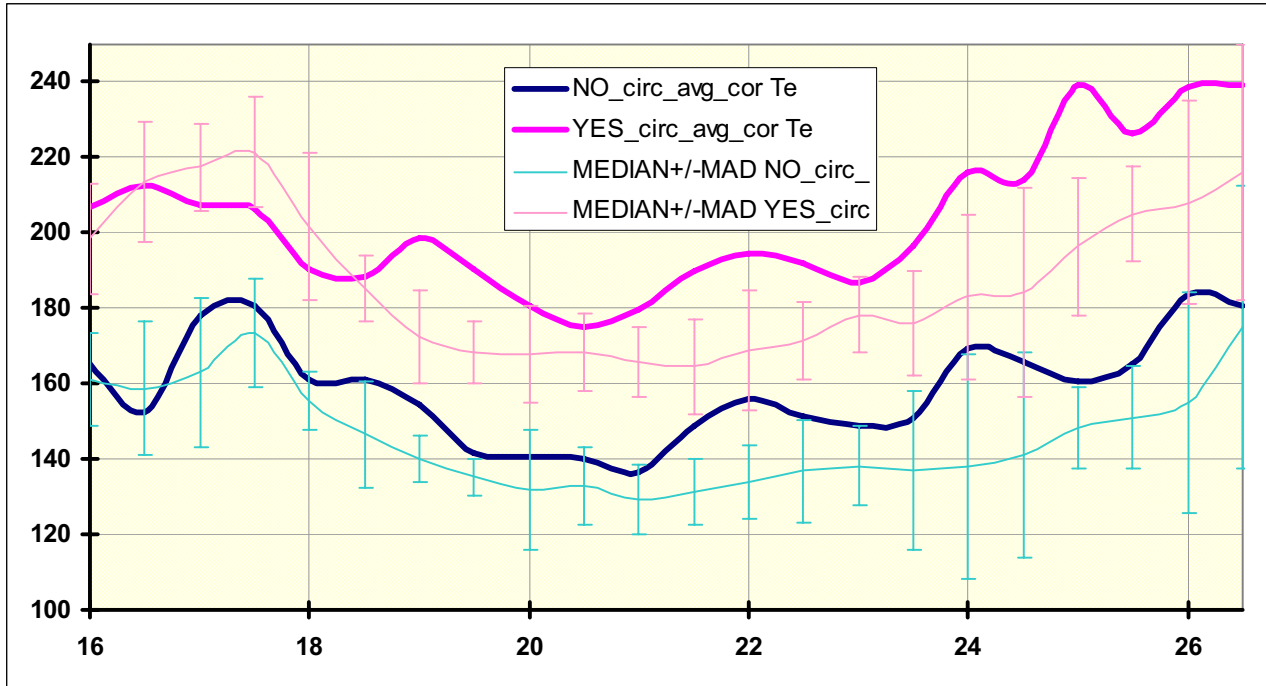


7 University of Cantabria, HP346CK01

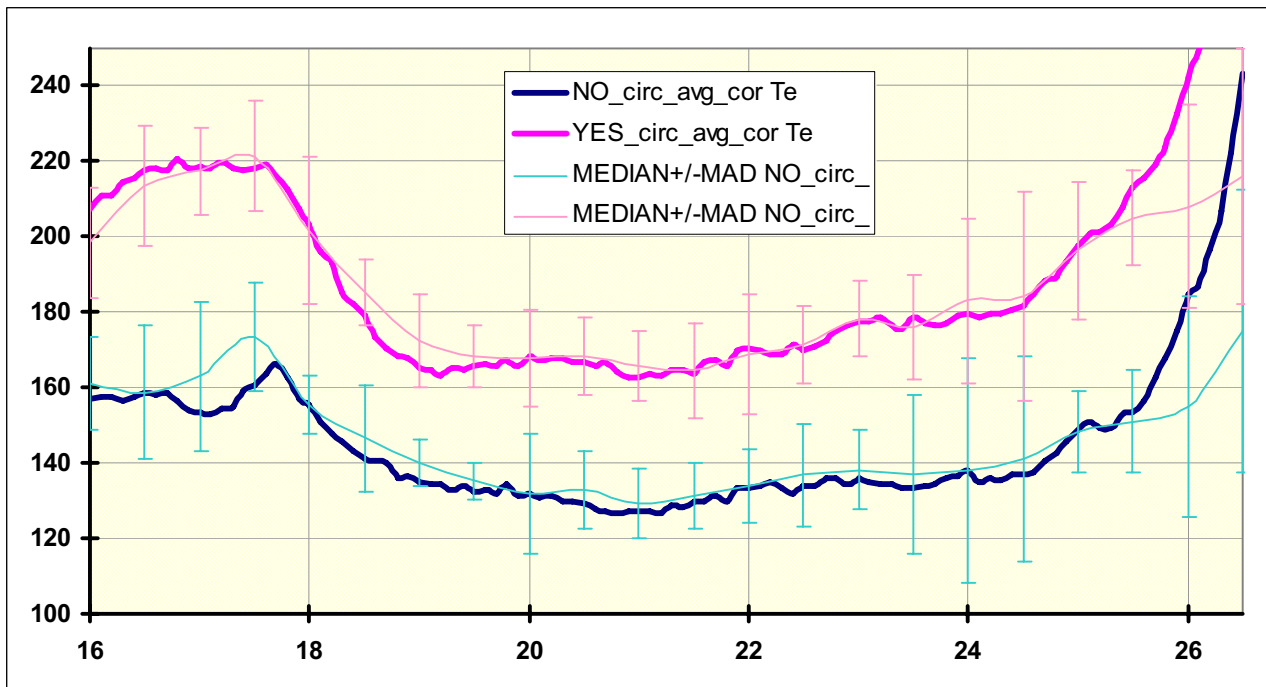


8 University of Cantabria, HP346CK01+10dB Attenuator

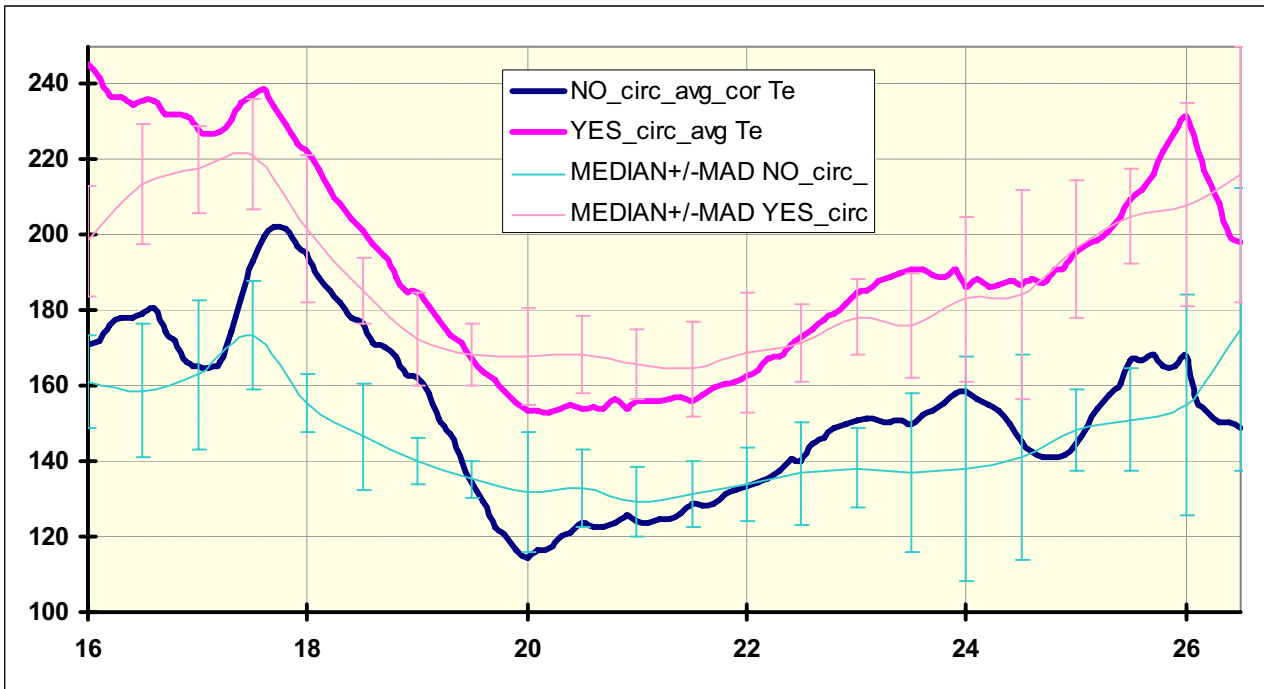




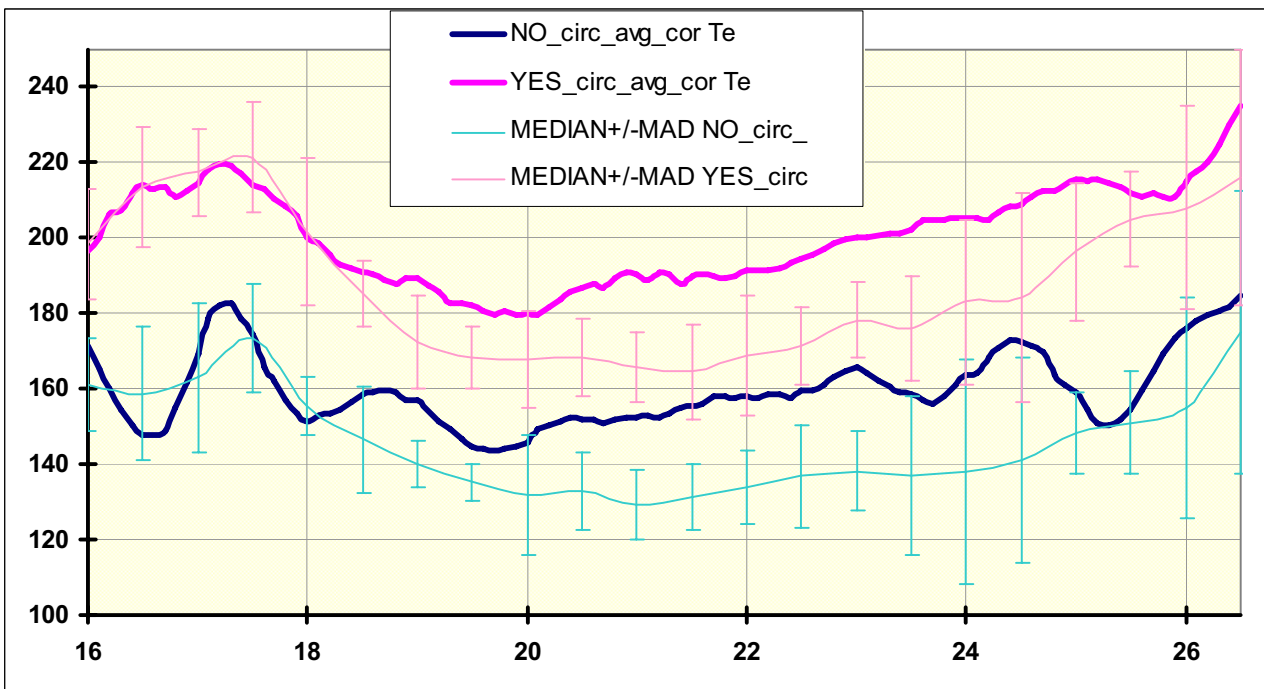
9 University of Manchester, SNS N4002A



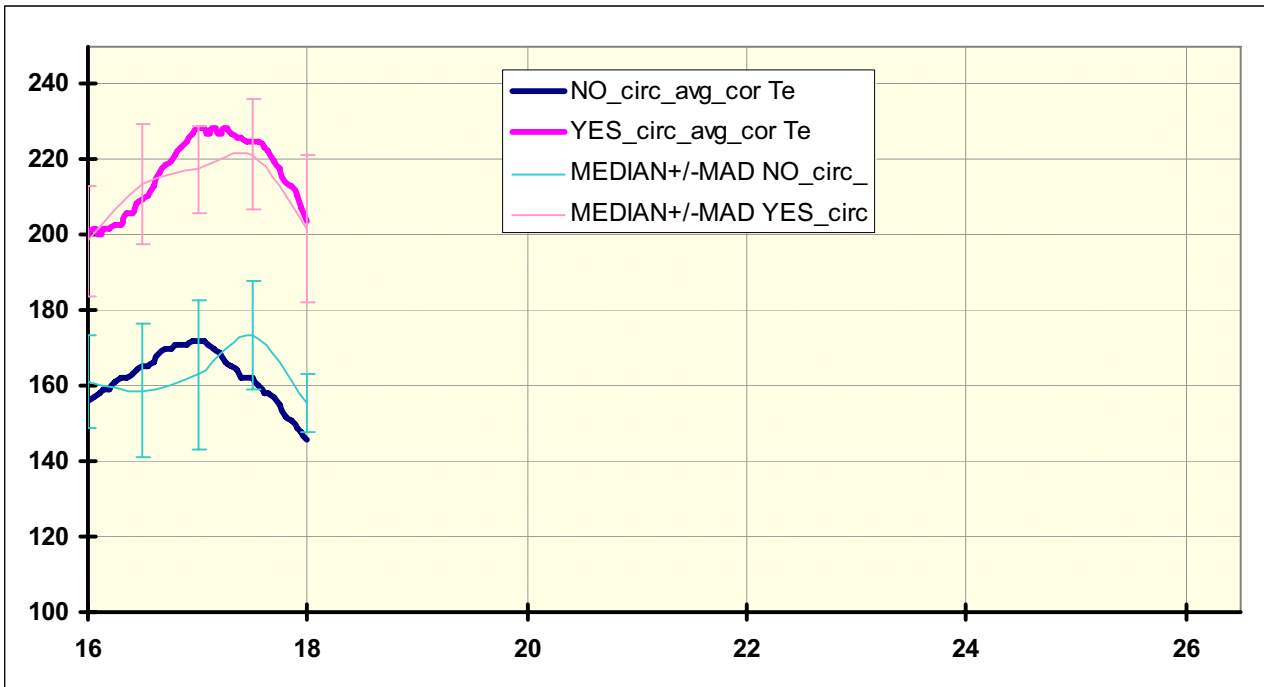
10 Centro Astronomico de Yebes , HP346C+10dB Attenuator



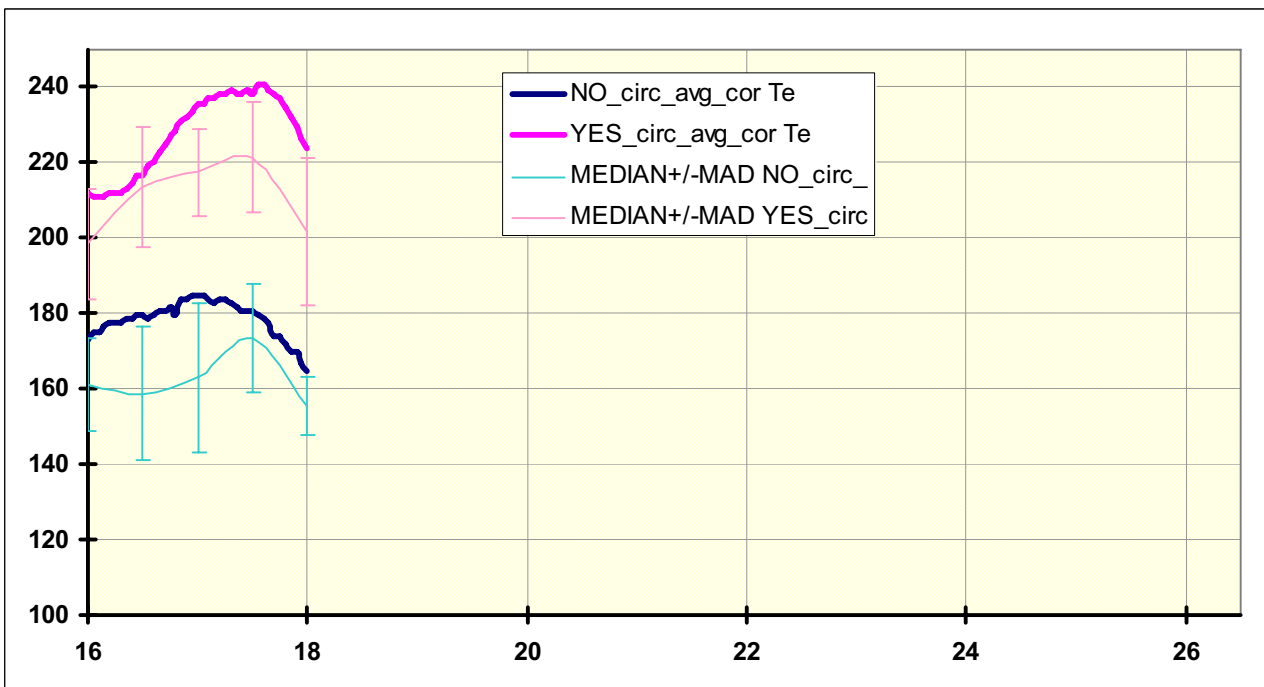
11 Centro Astronomico de Yebes, NC346KA+10dB Attenuator



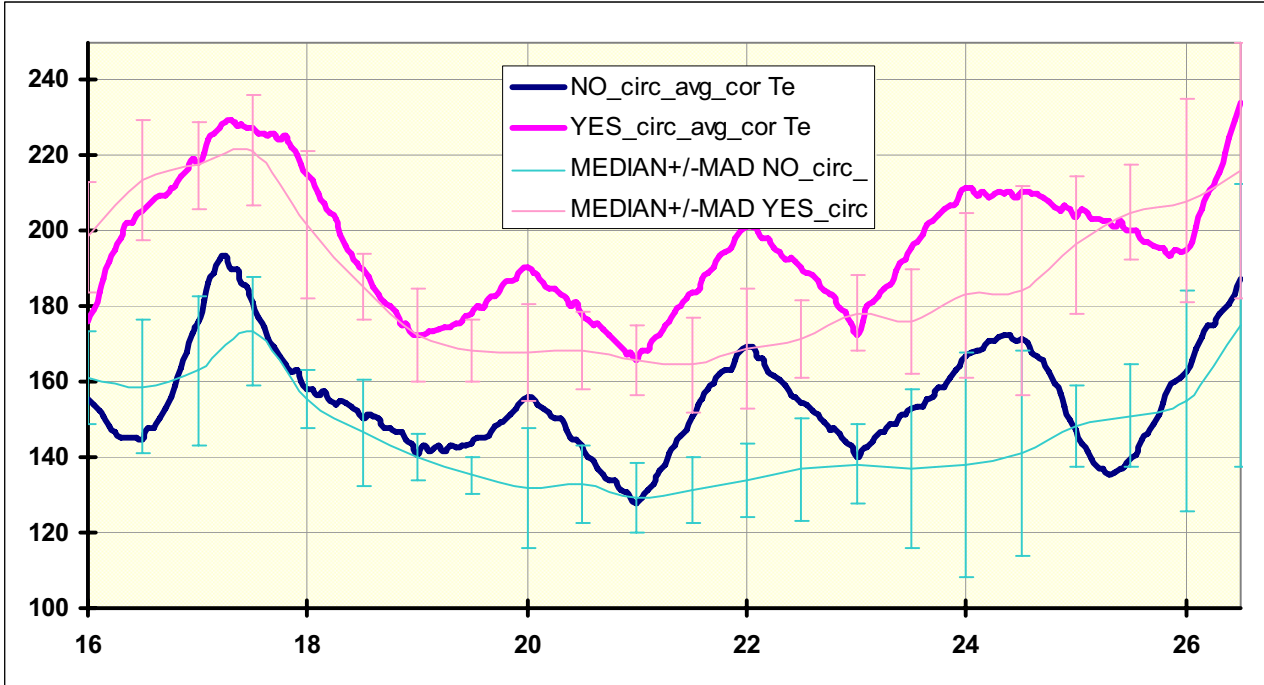
12 Centro Astronomico de Yebes, SNS N4002A



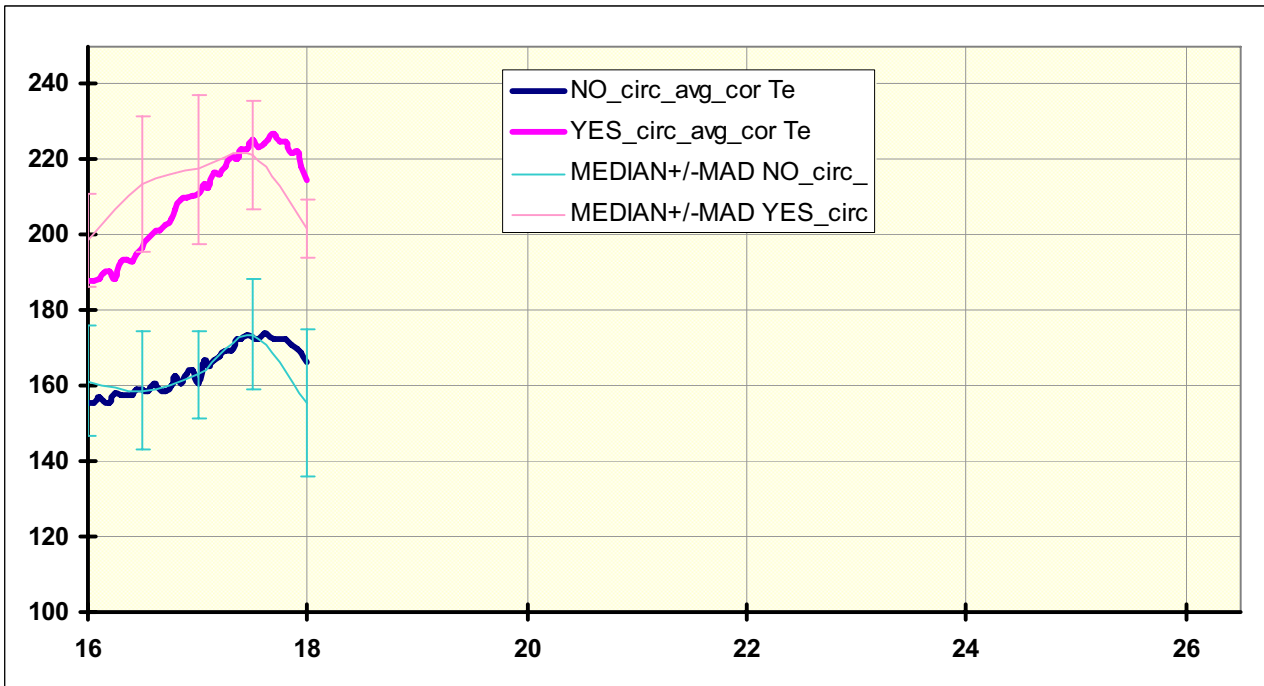
13 Astron, HP346A



14 Astron, SNS N4000A




15 Fraunhofer IAF, SNS N4002A



16 Fraunhofer IAF, SNS N4000



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## Trace behaviour, similarities and noise generators summary

In the following table the behaviour of the compared noise generators and the uncertainty labelled by the factory are summarized

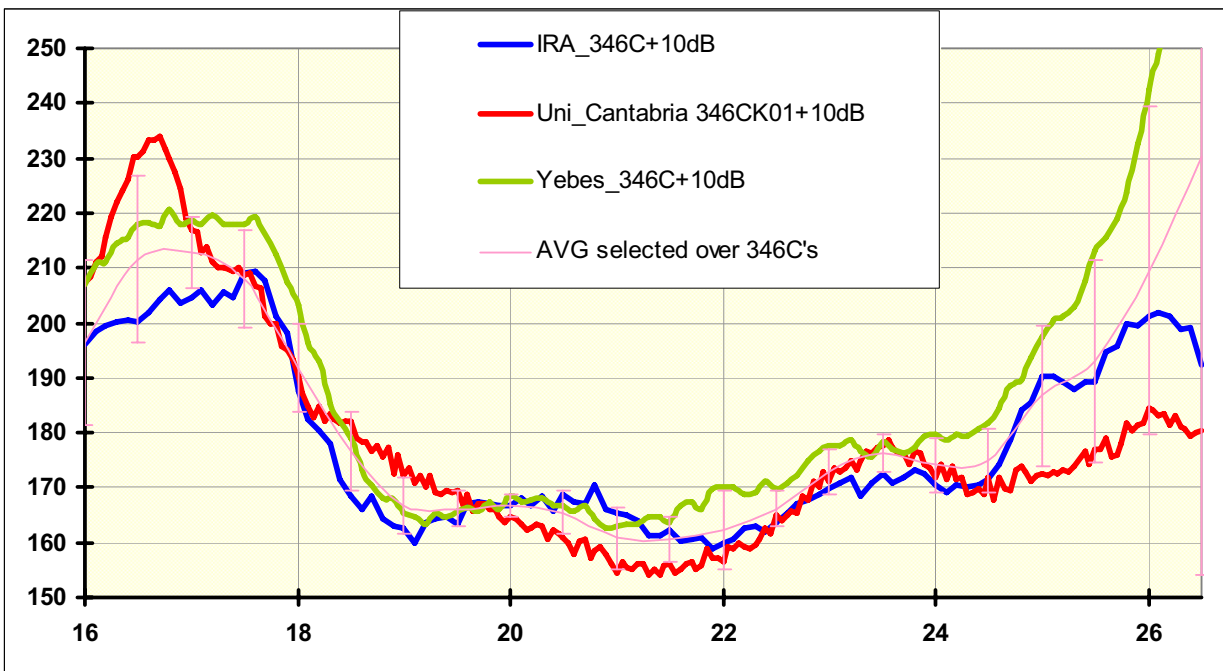
ORGANISATION	NOISE GENERATOR	Date	Freq. range	Similar behaviour	Uncertainty u(ENR)
Uni Cantabria	HP 346C K01 <sup>(1)</sup>	20/07/2009	16-26.5		+/- 0.12
Uni Cantabria	HP 346C K01+10dB	20/07/2009	16-26.5	■ CM	+/- 0.12
INAF-IRA	HP 346C +10 dB	03/09/2009	16-26.5	■ CM	+/- 0.06 <sup>(2)</sup>
INAF-IRA	HP 346A	17/08/2009	16-18		+/- 0.12
Uni Manchester	SNS N4002	30/10/2009	16-26.5	○	+/- 0.06
Yebes	HP 346C+10dB	30/11/2009	16-26.5	■ CM	+/- 0.12
Yebes	NC 346KA+10dB <sup>(3)</sup>	30/11/2009	16-26.5		+/- 0.12
Yebes	SNS N4002	30/11/2009	16-26.5	○	+/- 0.06
Astron	HP 346A	20/04/2010	16-18	CM	+/- 0.12
Astron	SNS N4000	20/04/2010	16-18		+/- 0.06
Fraunhofer IAF	SNS N4000	25/05/2010	16-18	CM	+/- 0.06
Fraunhofer IAF	SNS N4002	25/05/2010	16-26.5	○	+/- 0.06
INAF-IRA	HP 346C +10 dB	08/06/2010	16-26.5	Repeatability check	
INAF-IRA	HP 346	08/06/2010	16-18	Repeatability check	

Where:

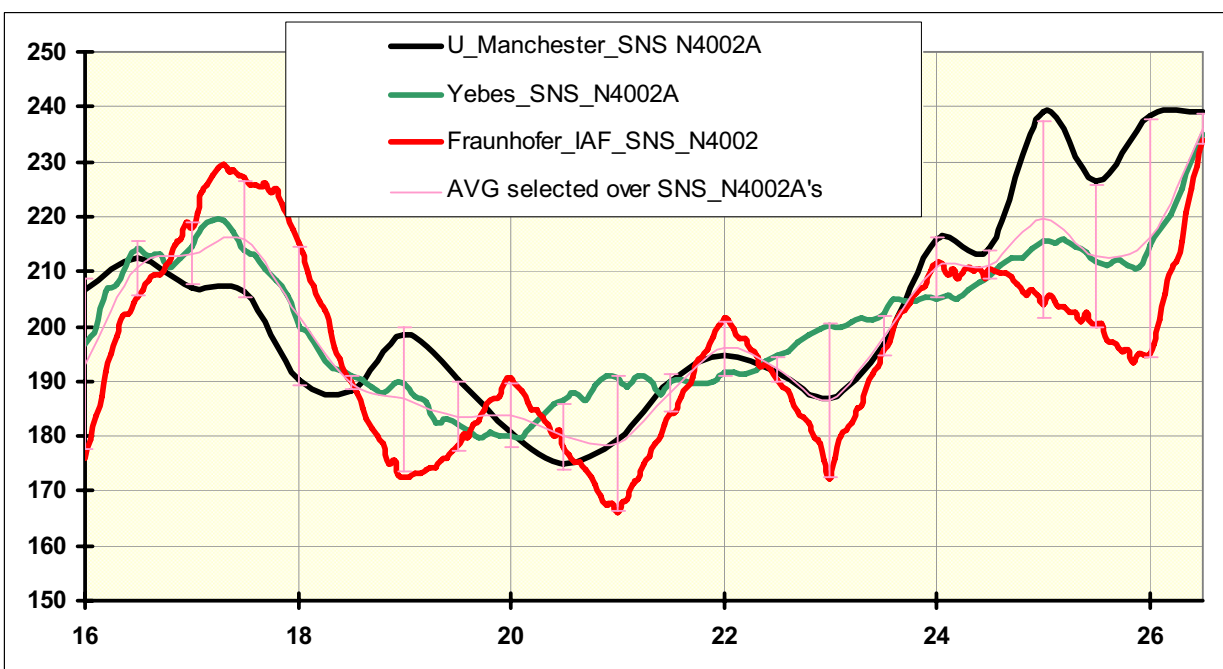
- (1) K01 stands for 1GHz...50GHz 2.4mm coax connector.
- (2) Uncertainty reduced by in-house calibration
- (3) KA stands for 10MHz...40GHz 2.92mm coax connector.
- the behaviour of the traces is similar among themselves
- the behaviour of the traces is similar among themselves
- CM the trace is closer to median value

It has been looked for the most similar curves. In the following two graphics are plotted the closest curves because the number of similar families of curves is two.







As it may be seen in the following charts, the measurements performed by laboratories that involves the *mod. NC346C + 10 dB attenuator* are closer among themselves. Also measurements performed by laboratories that involves the *SNS N4002* are among themselves. But the two families are different among themselves. It may be suspected that the differences may be imputed to differences in the original calibration procedures at Agilent factory.



17 Measurements performed with Noise Generators *mod. 346C+10 dB Attenuator* by different labs



18 Measurements performed with Noise Generators *SNS\_N4002A* by different labs

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## ENR TABLE CORRECTION

For laboratories like to correct their ENR table in order to reduce the distance from the average or median, a method is described.

It's important to write in an explicit way that this operation is conceptually a mistake for two reasons:

- A metrological mistake. The calibration of a Noise Source by the knowledge of  $T_e$  of LNA is same as the calibration of a pocket rule by comparing to the length of a table desk (while the right way is the contraire).
- A mathematical mistake. It isn't a rigorous method, it's just s an approximation. The reason is because for a rigorous calculation it should be necessary to know and take into account for the noise temperature of the Noise Figure Meter ( the Calibration data), while those data are unknown.  
However since the LNA gain is high enough, the Noise Temperature of the Noise Figure Meter is strongly masked, so accepting a small error, the Noise contribution of the noise figure analyzer may be neglected. In any case, even if it's an approximation the method is converging, so the error will be reduced and there is no risk of overcorrection.

But if the difference of ENR is suspected to be very large, a corrective action is perhaps better than do nothing. So, if the preceding simplification is accepted, the actual measured Noise Temperature is:

$$T_e = \frac{T_h - Y \cdot T_c}{Y - 1} \quad (1)$$

The similar equation form may be written for the value we would read, the corrected Noise Temperature ( $T^c e$ )







$$T^c e = \frac{T^c h - Y \cdot T_c}{Y - 1} \quad (2)$$

Now , let perform the ratio,

$$\frac{T^c e}{T_e} = \frac{T_h - Y \cdot T_c}{T^c h - Y \cdot T_c} \quad (3)$$

Solving for the corrected hot temperature  $T^c h$ ,

$$T^c h = \frac{T_h - Y \cdot T_c}{\frac{T_e}{T^c e}} + Y \cdot T_c \quad (4)$$

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Finally the new, corrected ENR value is:

$$ENR^c = 10 \cdot \log\left(\frac{T^c h - T_o}{T_o}\right) \quad (5)$$

Or , if the operator prefers the advantages of the small correction for  $T_c \neq T_o$  , even if formally different by the ENR definition, we get:

$$ENR^c = 10 \cdot \log\left(\frac{T^c h - T_c}{290}\right) \quad (5 \text{ bis})$$

Where:

- $T_e$  = Input Noise Temperature of the LNA ( the actual Noise Temperature)
- $T_h$  = Hot Noise Temperature generated by the Noise Generator (the actual value)
- $T_o$  = 290 K, The standard temperature
- $Y$  = The Y factor .
- $T^c e$  = Input Noise Temperature of the LNA ( the wanted value)
- $T^c h$  = Hot Noise Temperature generated by the Noise Generator (the wanted value)
- $ENR$  = The Excess Noise Ratio (the actual value)
- $ENR^c$  = The Excess Noise Ratio (the wanted value)

Note that the variables  $T_e$  and  $T^c e$  should not only be considered alone, but also their ratio  $\frac{T_e}{T^c e}$  has a physical meaning.

The knowledge of the variable Y is required but probably was not recorded at the time of measurement. It doesn't matter because the Y factor may be calculated offline by solving the (1) for Y and combining the (5) or the (5bis)

$$T_h = T_o + T_o \cdot 10^{\frac{ENR}{10}} \quad (6)$$

$$Y = \frac{T_e + T_o + T_o \cdot 10^{\frac{ENR}{10}}}{T_e + T_c} \quad (7)$$

In order to help users, who want correct their ENR table, a MS Excel file is provided. The user should input, frequency by frequency, the actual ENR, the actual  $T_e$  and the spreadsheet will calculate the ENR corrected that produce the median  $T_e$ .



## CONCLUSIONS:

The Noise Temperature measurement of a travelling LNA has shown strong differences among laboratories. Assuming as the major cause of uncertainty on Noise Temperature the uncertainty of ENR, the spread of the data is much larger than the expected.

Many of the Noise Sources were “lowest uncertainty type”, so there is no room for improvements involving the factory.

The only way to further reduce the uncertainty of the ENR is the calibration with a cryo-load that acts as a primary or secondary metrological standard. This is especially thru for the millimetre wave frequencies where the uncertainty is greater.

Because the cryo loads are very expensive (50000 – 100000 €) a join or consortium is suggested for the purchase, as well as a sharing in the use.







Perhaps the best way would be a common European Centre for Noise Source Calibration that involve metrological standard cold-loads as shown in the following pictures.



In any case, each laboratories that believe its ENR is wrong, has the freedom to correct it by using the algorithm provided.

## ACKNOWLEDGEMENTS

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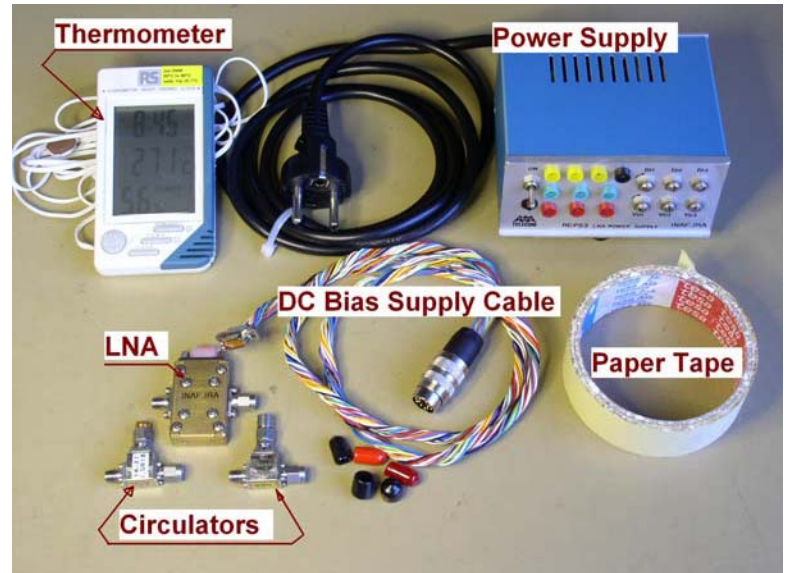
			<b>NOISE SOURCES COMPARISON AROUND THE EUROPE</b> <i>FINAL REPORT</i>		
			Author: Sergio Mariotti	Revised by: A. Orfei, J.D. Gallego	Date: Oct. 9 <sup>th</sup> 2010

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## Inside the cardboard box

Quantity	Description
1	Power supply
1	LNA
2	Ka Band ferrite circulators with 50 Ohm load.
1	Digital thermometer
1	paper tape
1	This manual



Please take care the cardboard box; it will be used for ship back to INAF-IRA.

## Frequencies

The optimal frequency range is 16.00 GHz ... 26.50 GHz

The steps must be 50 or 100 MHz wide, and includes the integers of GHz (i.e. 16.00, 16.05, 16.10, ... 26.50). Please do not acquire “strange” frequency numbers like 16.000, 16.0525, 16.105...

If Your own equipments do not allow the 16.00...26.50 GHz frequency range, You may perform the measurement in a limited portion of the bandwidth (i.e. 16.00...18.00 GHz or 18.00...24.00GHz).

## Operations

The operations are very simple and intuitive. But the quality of the result will depend even on the skill of the operator. The measurement require only one person. One skilled person is better than two or more non skilled people.

The estimated time needed for the measurement is 1-3 hours, additionally up to 3 hours are required for the logistics.

There is no need to known the principle of operation and the motivations, but if You are interested , You may download the presentation on:

<http://www.radionet-eu.org/fp7/wiki/doku.php?id=na:engineering:ew:1stew>

then right click on [Practical aspects on noise figure measurements](#) and “Save destination...”.

## The procedure

1. Turn on the Noise Figure Meter (NFM). Set LO power ( if required) and the central frequency (i.e. 22 GHz). Connect the Noise Source and let it chopping (switching ON/OFF quickly).
2. Open the cardboard box, put the power supply, LNA, thermometer and ferrite circulators on the table.  
Connect LNA to Power Supply, then Power Supply to the mains. The mains must be grounded properly.
3. Wait the warm-up time, typically 30 min for *hp8970A/B* (mode 1.1), *Eaton/Maury*, and *Agilent NFA*  
If You are using *hp8971B* (mode 1.5) , at least 2 hours of warm-up are needed.
4. The temperature of environment and the room should be as constant as possible, keep away from direct sunlight, far from air conditioner air flow etc etc.  
Also, the LNA should be far from the heated air flow coming out from the NFM and or other equipments.
5. Visual check of all coaxial connectors. They must be clean, free or dust, burrs, also check visually the integrity of coaxial cables. Pay attention when connect the circulators, they are expensive devices. Be gently with the connectors. If a circulator drops into the floor or has been mechanically shocked, please write it into the email report.
6. Calibrate the NFM. Use the ferrite circulator S/N 006 as front-end of Your NFM. The calibration plane is now at the input of the ferrite circulator (see Fig. 1).  
Set an adequate averaging ( not too long time, please!).  
Wait at least 5 minutes and check the calibration. Redo the calibration once again if far from 0 K.  
Record the file as `initial.*`
7. Insert the LNA by gently screwing the K connectors as usual (see Fig. 1).  
Put the thermometer sensor as close as possible to the end part of the Noise Source body (OUT connector side).  
Use the paper tape to firmly connect the sensor (see Fig. 2). Paper tape is more thermal isolator than other tapes, also it can be peeled away quickly.  
  
*note: even in the case You are using an interseries coaxial transition ( i.e. 7mm to SMA or N to SMA) the thermometer sensor should be placed closer as possible to the end part of the Noise Source body.*
8. Wait 5 minutes for the thermalization. (Your finger has been heated the LNA ! )

9. If You are using *hp8970* or *hp8971* or *Maury/Eaton* NFM :  
Read the temperature on the digital thermometer, convert in K if necessary, put it into the NFM ( for *hp8970* type 6.0 SF) and writes to me by email.  
If You are using the new *Agilent NFA*, read both the digital thermometer and the actual Cold Temperature of NFA and writes to me by email both.
10. Perform the measurement (without ferrite circulator at the input of LNA). Record the file as `no_circulator.*`
11. Disconnect the Noise Source, insert the ferrite circulator s/n 004 (see Fig. 3).
12. wait 5 minutes, check once again the cold temperature, and if necessary set once again into NFA.
13. Perform the measurement (with ferrite circulator at the input of LNA). Record the file as `circulator.*`
14. disconnect the LNA and connect the Noise Source to NFM.
15. Wait 5 minutes and perform the 4<sup>th</sup> and last measurement. This is a 0K check in order to know the drift during the procedure. Record the file as `final.*`
16. The measurement is finished. Put the LNA, ferrite circulators and all the materials into the cardboard box , and ship back .
17. Send an email to [s.mariotti@ira.inaf.it](mailto:s.mariotti@ira.inaf.it) containing the following:
  - 1 - **The four text files.**
  - 2 - **The value of Cold Temperature.**
  - 3 - **Type of conversion (SSB or DSB ?)**
  - 4 - **A brief description of the setup including the equipment p/n.**
  - 5 - **Name and contact of the person that really have made the measurement.**
  - 6 - **The tracking number of the shipment.**
  - 7 - **Some additional in formations if necessary or needed.**

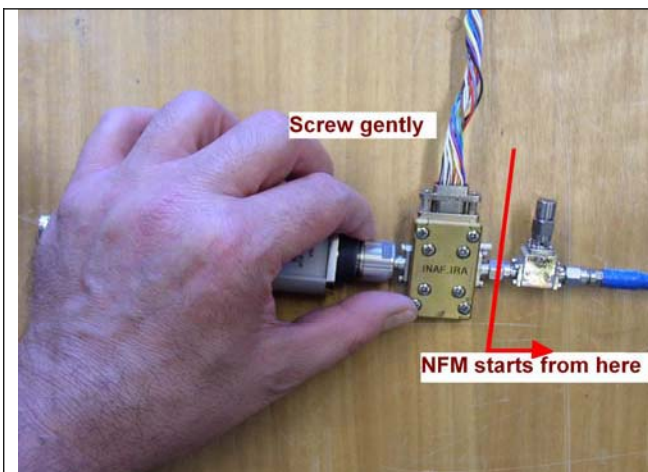


Fig. 1 Screwing the coax connector

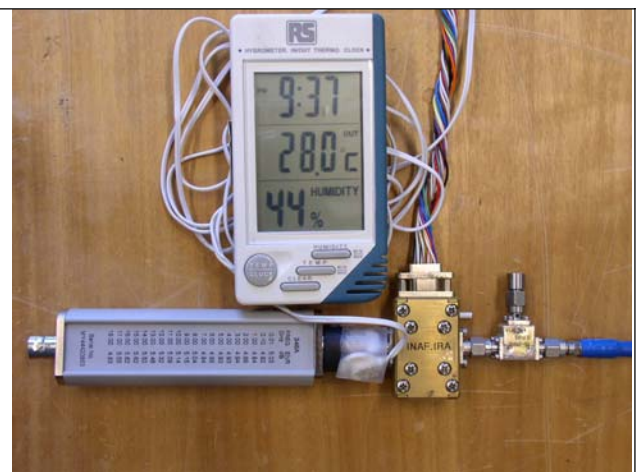


Fig. 2 The thermometer sensor is installed



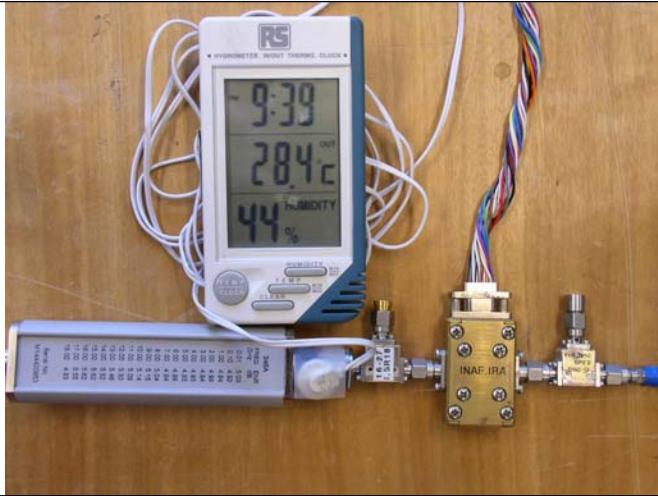


Fig. 3 The ferrite circulator in front of the LNA

## Expected Results

Once all partner will have performed the measurements, the data will be collected and plotted together on the same graphic, The plot will be sent to all partners.

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