MEMO

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PAON2-OptX21cm/27.02.13

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Subject: Summary of some Electronic Test Bench analysis at LAL

1 Introduction

In the continuity of references PAON2-OptX21cm/15.02.13rev, 16.02.13, 19.02.13, 22.02.13 a summary of systematical cross-checks have been performed concerning the oscillations with cable & LNA & OL homemade/OL synthesized.

2 The setup and results

The setup is essentially the same used in the above mentioned MEMOs but we have also used rigid coaxes 2m long or 15cm long. We have also redone some run configurations just to see if the conclusions remains valid, and (un)fortunately the answer is Yes. So I take the opportunity to draw some personal view on strategic plans. Just a reminder, all data taking was done at 1kHz with 2 fibers on RAW mode and FFT done online by the "monitoring daq program" running on pc-sitr2 rather slow machine (40'). Mean spectra avec 2500paq ~2.5s are used as basic analysis input. No filtering in any sense is applied. So the answer of a particular configuration is quick and most of the feature may be seen online.

2.1 With LNA & OL synthesized

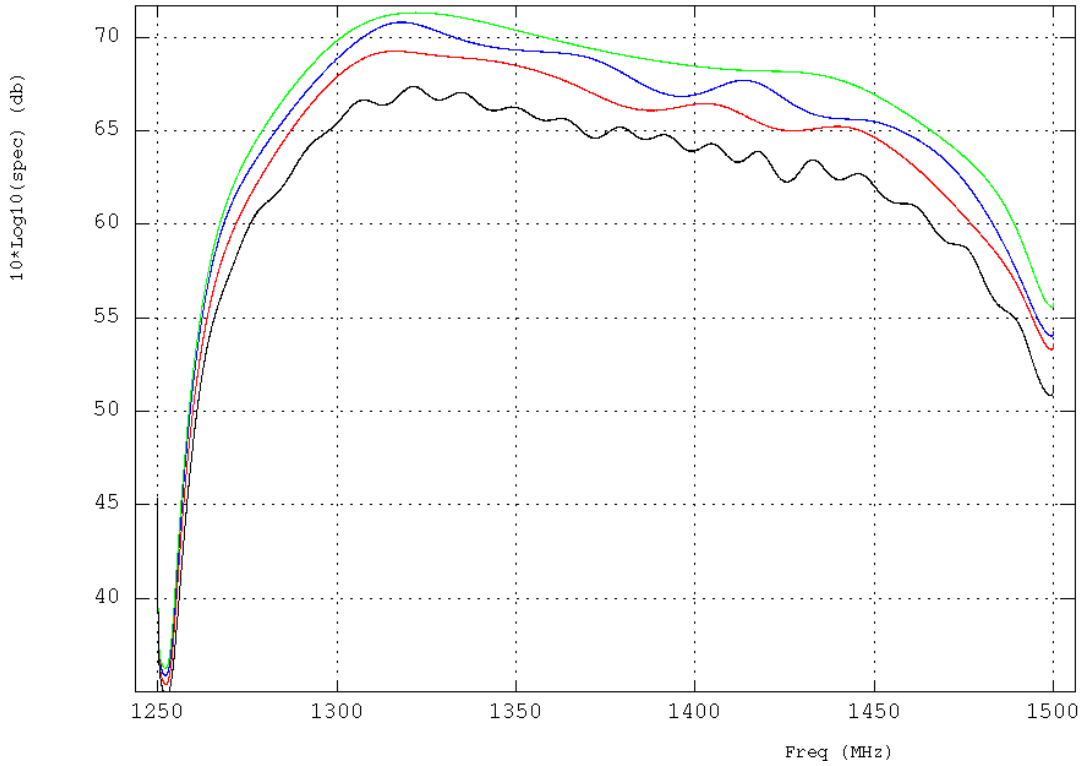


Figure 1

On Figure 1 it is shown 4 setup results which only differ from the type and the length of the cables at the entry side of the mixer. The other side of the cable is connected to the homemade LNA and itself terminated with a 50Ω load. Here are the different setups:

- Green curve: 15cm of rigid coax
- Blue curve: 2m of rigid coax
- Red curve: 2x1m of flexible coax
- Black curve: 7m of flexible coax

Comparing blue and red curves, we can see that concerning the oscillations/modulations of the spectra, the fact that rigid coax has a natural better tolerance on their impedance characteristics shows that the source of the oscillations is not on the cable side.

Comparing the green, blue, black curves show clearly the dependence of the oscillations/modulations "wave length" with respect to the cable length:

- with 15cm it is hard to define a "wave length"
- with 2m it is ~48MHz
- with 7m it is ~14MHz

From these numbers we get an empirical relationship of the type: $\Delta\nu\ L \sim 96$ MHz.m.

Two remarks may be addressed from these results. The first one concerns the data taking at the NRT. During the HICluster data taking we have observed (J.E.C and A.S.T Nancay/Amas/09.02.12 & Nancay/Amas/13.02.12) spectra modulations with 3-5MHz "wave length" with sudden $\pi/2$ phase changement. Does it mean that the connection between the "coupler" picking the signal of the standard NRT chain and the BAO mixer was for some

times of the order of 24m? Anyway it is vital for the OptX21cm program coming soon, to reduce this length as much as possible and make a test in situ.

The second remark concerns the PAON and future dish array. The fact that the spectrum modulation wave length decreases inversely proportional to the cable length strengthen a “as close as possible digitization” R&D program which would focus on small card with digitization close to the dish LNA and send in full streaming the BAO paquet other optical fiber to a concentrator & visibility calculator “à la Uniboard” even if alternative might be worth to be investigated too.

2.2 Without LNA but with OL synthesized

At first glance using setups without LNA can be considered as a waste of time. In fact after looking at spectra, it reveals the thin lines series that was thoroughly studied in HICluster data where the NRT LNA is refresh by a cryogenic system (see J.E.C and A.S.T Nançay/Amas/16.03.12 and Nançay/Amas/4.04.12).

On Figure 2 we have used 15cm rigid coax (blue curve) and the 2m rigid coax (red curve) and the OL synthesized as in the previous section. First we see hardly the intrinsic modulation of the spectra by the cable length in these two examples. In a next figure (see below taken with homemade OL) it is shown that 7m long cable reveals clearly the problem, but I would recommend the investigation of the spectra modulation reduction using the homemade LNA.

Secondly, it is clear that a line forest emerges with similarities to those observed at HICluster data. Notice also that the 1385MHz line (particularly visible in the red spectrum) is an intermittent line as shown on Figure 3. The intermittency of this line reveals a shielding weakness of the present system.

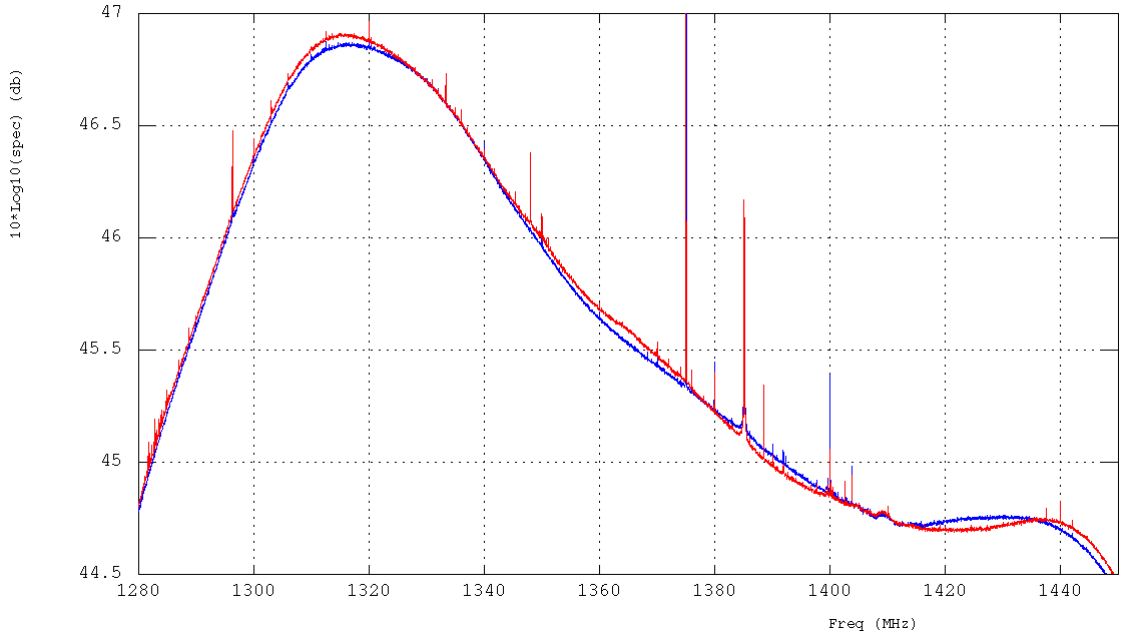


Figure 2

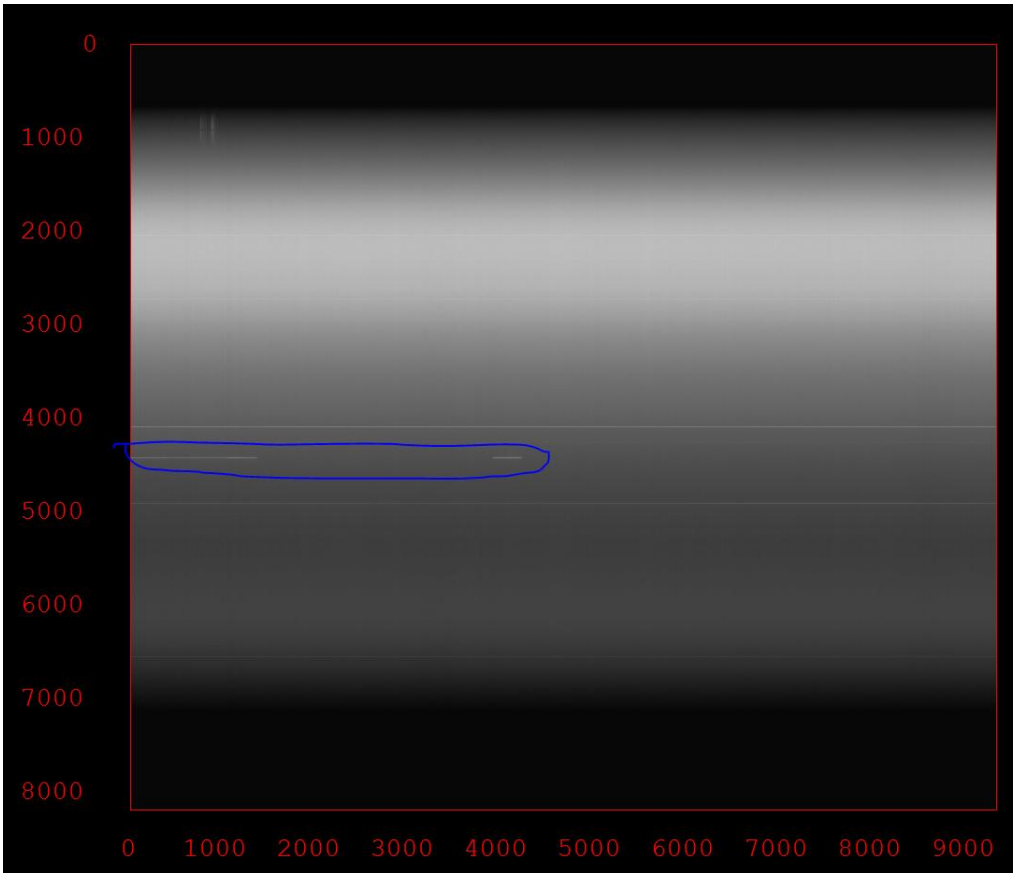


Figure 3 Proof of intermittency of the 1385MHz line. This was performed during the night 21/02-22/02 cumulating 15h of data with ~5sec sampling.

2.3 Without LNA but with homemade OL

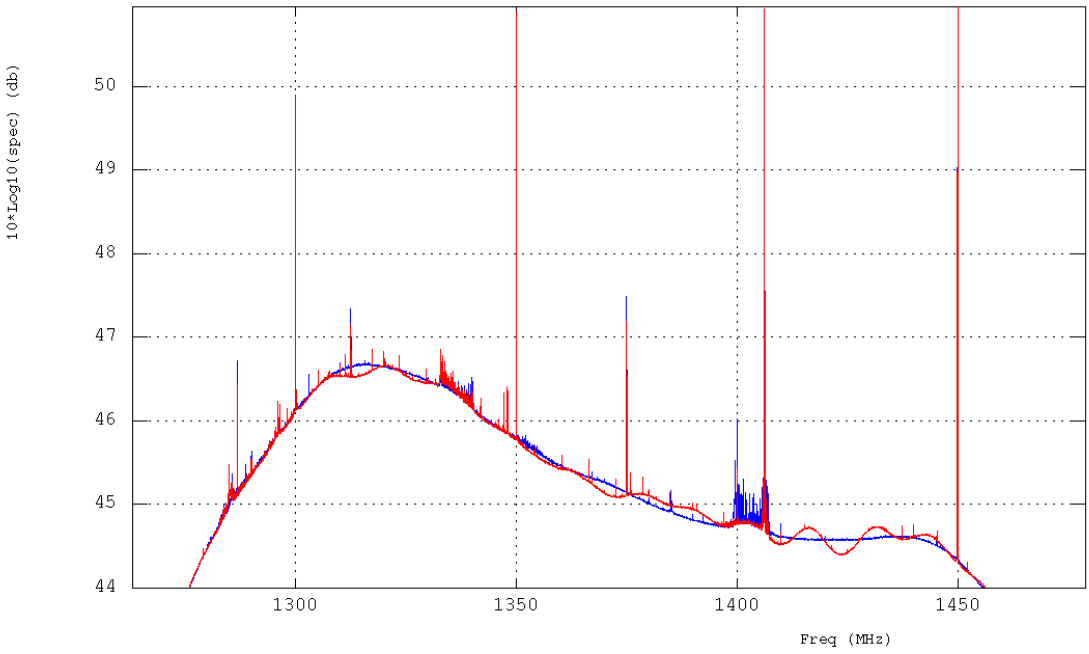


Figure 4

On Figure 4 it is displayed two spectra done with the "homemade" OL at 1250MHz and using 2m rigid coax (blue curve) and 7m flexible coax (red curve). First we see that 7m cable

reveals the modulation pattern of the spectrum even without LNA. Secondly, it is clear that already shown the OL produce spurious and powerful lines and also some frequency band region are completely saturated by these lines: for instance [1330, 1340]MHz, [1398, 1408]MHz. It is clear that for the forthcoming OptX21cm observation one will need a cleaner OL either by renting/buying a synthesized OL, either using a different parameter tuning of the present OL if possible.

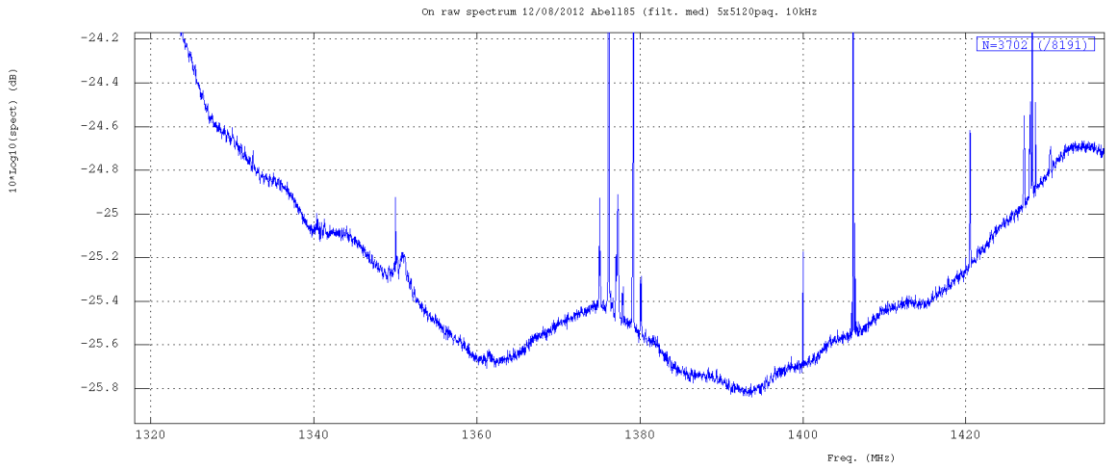
3 Summary & Outlook

In this MEMO, I have presented new results and revisit some which were already discussed in previous MEMOs.

Concerning the very soon forthcoming OptX21cm observation program which will take place at the NRT in the same configuration of the HICluster although in a different frequency band [1120-1370]MHz, we must take drastic decisions as:

- Use shorter cables (rigid or not that does not matter as far as it was investigated so far) in a range less than 7m (keep in mind $\Delta\nu$ L ~ 96 MHz.m);
- Use a cleaner OL. A possible location of a synthesizer would be appreciate over wise this will represent a few k€ dedicated investment.
- The local distclock as well as the portable PC might be not used as much as possible (for instance the test bench trigger has been driven by a remote control oscilloscope through Ethernet connection).

It is clear that very rapidly the problem can blow up at our faces. As a reminder on Figure 5 is shown data from an Abell85 run taken 12/08/12 (no selection criteria were used to pick up this run).



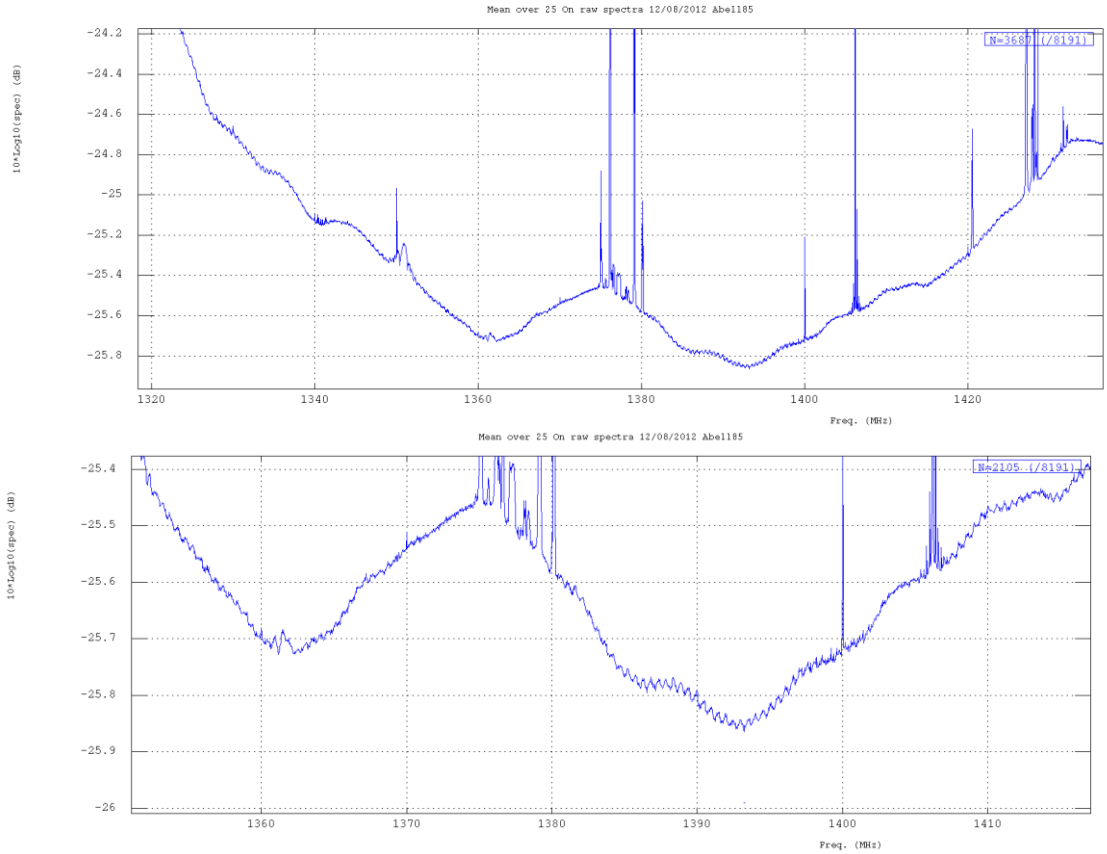


Figure 5

On top is a single 'ON' (without gain normalization) which the mean over 5 spectra resulting each on a median filtering over 5120paq (trig. 10kHz RAW firmware) for each 33kHz frequency bin (standard analysis). One can see the spectrum modulation, the 1406MHz composite line and so on. On the middle and a zoom on the bottom panel is the mean of previous spectrum over a complete run (25 spectra during the ON/OFF data taking lasting 50'in real time). One can see the 'ultimate' problem that we will encounter very quickly: the small modulation of the spectra at very high frequency, the 500kHz, which is attributed to "optical" interference but no configuration has demonstrated that we can eliminate them without losing the HI signal itself.

Concerning the ongoing PAON-like R&D, it is clear that the analogical cable length is a problem for the array deployment in a 100m x 100m area. Recommendations have been listed to investigate both the modulations/oscillations of the spectra which are a clear signature of a mismatch between the cables and the mixer. These observations and the power law which has been empirically found motivate a refreshing of the electronics with the so-called "as close as possible digitization" R&D axis. It is manifest that this R&D is of higher priority from my point of view than improving the T_{sys}/η parameter by few percent for the future of intensity mapping measurement.