

## Response to Change Request ALMA-40.00.00.00-200 on Band 6 IF Frequencies

This CRE has been discussed by both the ASAC and at a recent Science IPT meeting. In both meetings there were strong views expressed that this CRE represents a significant loss of capability and that it should be resisted. As is clearly stated in the System Requirements, an IF frequency extending below 5 GHz is required in order to make simultaneous observations of the main CO line at 230 GHz and the isotopes near 220 GHz. Making these observations simultaneously not only increases the efficiency but will also reduce errors in comparing the structures seen in the different lines since many forms of error will cancel in that case. The view from scientific perspective therefore is that this capability should not be sacrificed.

In its present form, the CRE mixes together several issues:

- 1) the actual noise performance of the mixer-preamplifier combination
- 2) the slope on the IF output.
- 3) the excess noise generated in the LO system.

In summary, the Science IPT recommendation is that the noise requirements should continue to extend down to 4.5GHz, but that a relaxation on the slope requirement should be accepted.

The logic is that, since the use of the low end of the band is focused on spectral line observations, the slope is not so critical as it is for broad-band measurements. The digitization is of course always over a 2 GHz band, so digitization noise will be the main problem. The slope in power is always upwards as a function of frequency so that implies we should put the center IF frequency as low as possible so that there is plenty of power in the part of the spectrum that we are interested in (the two CO lines will be close to 5GHz in the IF). It is likely that we would be using the Tunable Filter Bank for these cases so we have 3 bits, which also reduce this effect.

I suggest that the criterion on slope should be no more than 6dB more power at 6GHz than at 5GHz. I think that even the worst case shown in figure 5 of the CRE would meet this. If the band 6 people can accept a limit of 5dB so much the better. (We should try to check what the effects really are for these cases where there is a big slope right across the band and we are interested in a relatively narrow section in the middle.)

As far as the noise temperature is concerned, I suggest that the specification should be for an SSB receiver temperature (averaged over both sidebands) of 83K at an IF frequency of 5GHz and an LO frequency of 225GHz. (I think these frequencies are close enough to those required for the 12CO and 13CO rest frequencies of 230.54 and 220.40 and allow for some red-shift.)

It appears from Figure 2 of the CRE that a small fraction of the mixer-preamps will fail this, but it is not stated whether the histogram is for all LO frequencies or just 225GHz, which is the relevant one here, and whether or not these plots include cases where there is excess LO noise. Going back to John Effland's memo, which is RD3 of the CRE, it appears that noise from the preamplifiers should not be a problem and there is no obvious reason why different SIS mixers would change the noise as a function of IF frequency much.

Turning to the excess LO noise, this seems to be a different class of problem. From the noise temperature plot, Fig 1 of the CRE, it is clear that a small fraction of the WCA's are adding a great deal of excess noise at 4 to 5 GHz for some LO settings. Figures 3 and 4 show that, for that particular WCA at least, this problem is unfortunately worst at just the relevant LO frequency of 225GHz.

I would argue that WCA's with such a large amount of excess noise should not be accepted and that this should be done quite independent of issue raised in the CRE. There are at least three

reasons why one would be extremely concerned about operating with an LO that generates so much excess noise:

1) Although the noise has the appearance of being broad-band, since it is being produced in a series of amplifiers and multipliers which are operating in a non-linear regime there is at least the possibility that it contains coherent components that are products of frequencies in the LO system.

2) Even if we are operating with an IF of say 6 to 10GHz, this noise is of course seen by the SIS mixer and the IF preamplifier. It will therefore contribute to any non-linearities in those parts of the system and it could well have an effect on stability.

3) The presence of noise on the LO implies a loss of coherence when doing interferometry.

Just to spell out this last point, one can think of the action of the mixer as being, to first order, a convolution of the spectrum of the incoming astronomical signal with the spectrum of the LO. I think this means that noise on the LO at say 1 GHz moves signal from its proper place in the IF to places that are +/- 1 GHz away. Obviously this produces loss of coherence which is proportional to the power in the noise sidebands on the LO. Now it may be that the noise power on the LO is in fact negligible in the relevant region (essentially from 0 to 4GHz) despite the appearance of the plots, but at the very least this needs to be checked.

Even if all three of these points are non-issues, the question of whether or not we can and should build Band 6 WCA's that meet the excess noise requirements at 4.5GHz and above is quite separate from the ones that are associated with the performance of the cold cartridges. The cost and schedule implications keeping the WCA requirement at the level necessary to meet the noise specification proposed above should be considered separately from the cartridge issues.

Finally, the question was very reasonably raised at the ASAC as to why on earth we being asked about this now (and in terms that more or less say that we have no choice but to accept this CRE) instead of when the problem was identified. It appears that FE has proceeded for the last several years with specifications on the Band 6 cartridge that are inconsistent with the FE Spec and the System Spec. It is clear that this issue was understood at least as early as 2006 when John Effland's memo was written. Note that this memo specifically proposed that the cartridge specifications should be tightened "to prevent scheduling and production demands from further degrading performance outside the 6-10 GHz band". That was impressively far-sighted of him and what he was trying to avoid is of course exactly what is now happening.

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18<sup>th</sup> Sept 2009