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To: IVS VGOS Technology and Operations Groups
From: A. E. Niell
Subject: Effect of warm dewar on system temperature and on geodetic results for GGAO-Westford baseline in session vt7254 (2017/09/11)

Introduction

Six hours into VGOS session vt7254 (17SEP11, expt 3618) the dewar at GGAO began to warm up due to a leak in the helium line. In this note the effect of the warm receiver on the delay uncertainty and on the geodetic estimation is investigated.

Effect of loss of cooling on T_{sys} and SNR

The increased system temperature affects the delay uncertainty by reducing the cross-correlation amplitude and thus the signal-to-noise ratio (SNR). In one form the SNR is given by

$$\mathrm{SNR} = S_C * \frac{\sqrt{2BT}}{2kb} * \sqrt{\frac{A_{eff1}A_{eff2}}{T_{sys1}T_{sys2}}} \tag{1.1}$$

where S_c is correlated flux density, B is recorded bandwidth, T is integration time, k is Boltzmann's constant, b is a correlator-specific scaling factor for digital correlation (for a 2-bit DiFX correlator the value is 1.1689 (from RJC: emails of 2013 Jul 20 and 2013 Oct 9), A_{eff} is the effective area of the antenna, and T_{sys} is the system temperature.

If no other parameter changes, such as integration time, the SNR is proportional to $1/\sqrt{T_{sys1}T_{sys2}}$. The system temperatures from the full logs are shown in Figure 1. The vertical scale is uncertain since it is determined by the value set for the noise-diode, and this is not well calibrated. For Westford the value is clearly off since other measurements suggest the mean value should be at least three times higher. The important feature for Westford is the constancy of the mean value over the 24 hours. Thus any change in SNR can be attributed to GGAO.

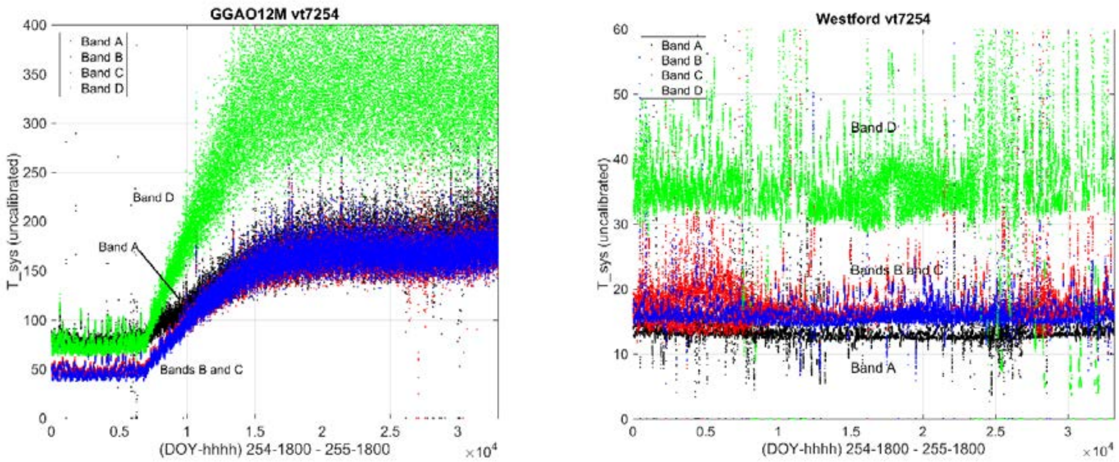

Figure 1. T_sys for X(H)-pol channel 8: left: GGAO; right: Westford (see text regarding the vertical scale)

An accurate value of the system temperature is not important for the current study, however. At issue is whether the decrease in SNR is consistent with the increase in system temperatures. In addition, there is value in demonstrating the time evolution of the system temperatures following the loss of cooling.

The median T_{sys} for the first twenty minutes for GGAO for Bands A-D are 77, 48, 45, and 72 K. Late in the session (~12:00 to~15:40 UT; the session ended at 18:00 UT) the median values are 179, 164, 166, and 340 K. The ratios of T_{sys} near the end to that at the beginning of the session are 2.26, 3.42, 3.69, and 4.7. The mean value is 3.5 for which the square root is 1.9. Thus the SNRs should be decrease by 0.53 through the session if the system temperature is the only cause.

It may be of interest to note that the system temperature began to rise sharply soon after the loss of helium pressure was noted, and that the maximum value was reached in about six hours.

The SNRs for all sources of the entire session are shown in Figure 2. Certainly the perceived approximate decrease from beginning to end is consistent with a factor of approximately two.

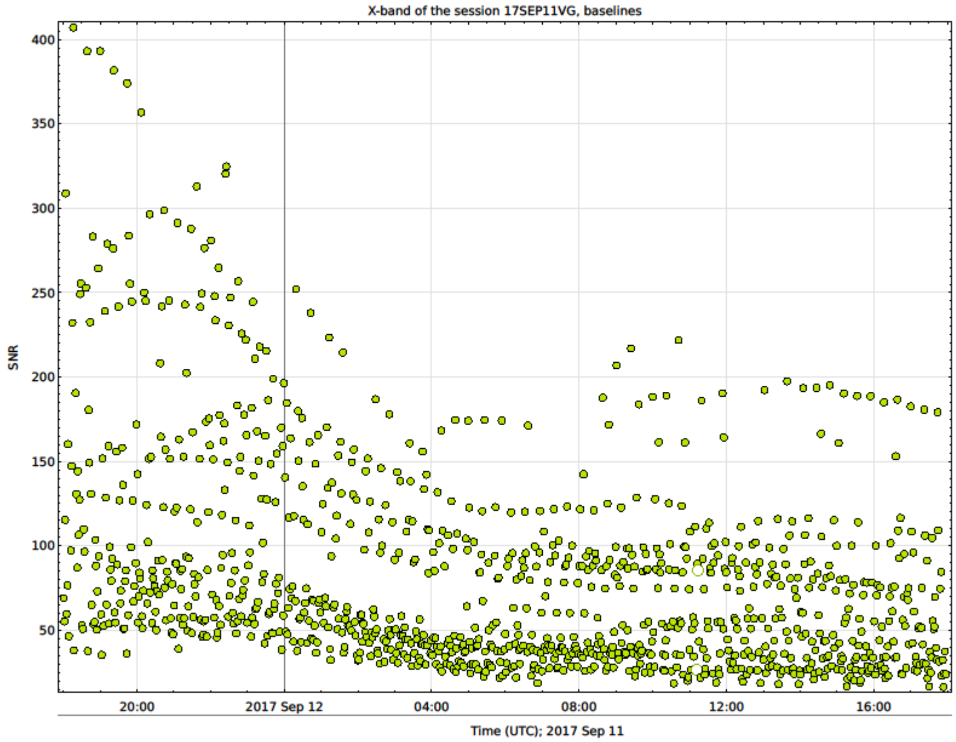

Figure 2. SNR vs time

To be more quantitative I extracted the SNRs for three sources from the a-list for the *fourfit* IXY polarization results, which are the data from which the vgosDb database is formed. For 0552+398, OJ287, and 1156+295 the ratio of amp(end)/amp(beginning) are 0.55, 0.52, and 0.49 for an average of 0.52, which is consistent with the expected ratio of 0.53 (almost too good!).

Almost no sources were not detected, even with the warm receiver. There were only ten non-detections out of over 2000 scans on the three baselines among GGAO12M, WESTFORD, and KOKEE12M. This is consistent with the observed reduction by a factor of two of amplitude and SNR since the minimum SNR for scheduled observations was 15 for both S and X (sked does not know about four-band observations), so the expected minimum IXY SNR would be about 40 (sqrt(8)*15), which would fall to 20 with the warm receiver. In fact the minimum SNR is higher than this for most scans since the scan length has a fixed minimum value of 30 seconds.

If in the future shorter scans are contemplated in order to increase the temporal density, thought should be given to deciding if the minimum SNR can be reduced at the risk of becoming more sensitive to a warm receiver. If the shorter scans are accompanied by a higher data acquisition rate, e.g. by recording all available channels, then the SNR buffer can be maintained.

Effect on geodetic estimation and post-fit delay residual

For the non-reweighted estimation of the baseline length, the WRMS value of the post-fit delay residuals for the beginning 20 minutes (for comparison with the system temperatures above) is 10.7 ps, while for the later period (~12:00 to~15:40 UT) it is 13.2 psec (Figure 3). This would correspond to an increase in system temperature at one station of about 1.5. But there are other sources of noise, such as variations in the atmosphere delay, so it is not surprising that this value is less than 2. If the other sources of error are reduced, the impact of the increased system temperature will be more significant.

Similarly, for the solution for which an additional delay noise has been added in quadrature (Figure 4), the PFDR increased from 13.2 to 17.2 ps, which is only a factor of 1.3. But now the system noise that is not due to only system temperature has been increased further.

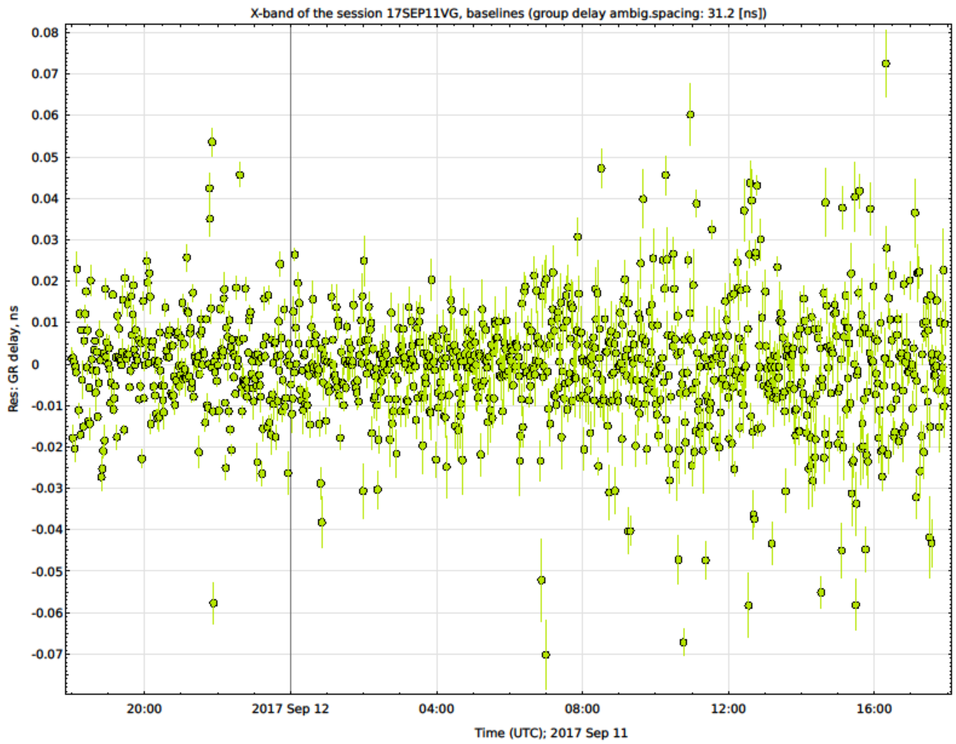

Figure 3. Post-fit group delay residuals (PFDR) (no_reweight) vs time

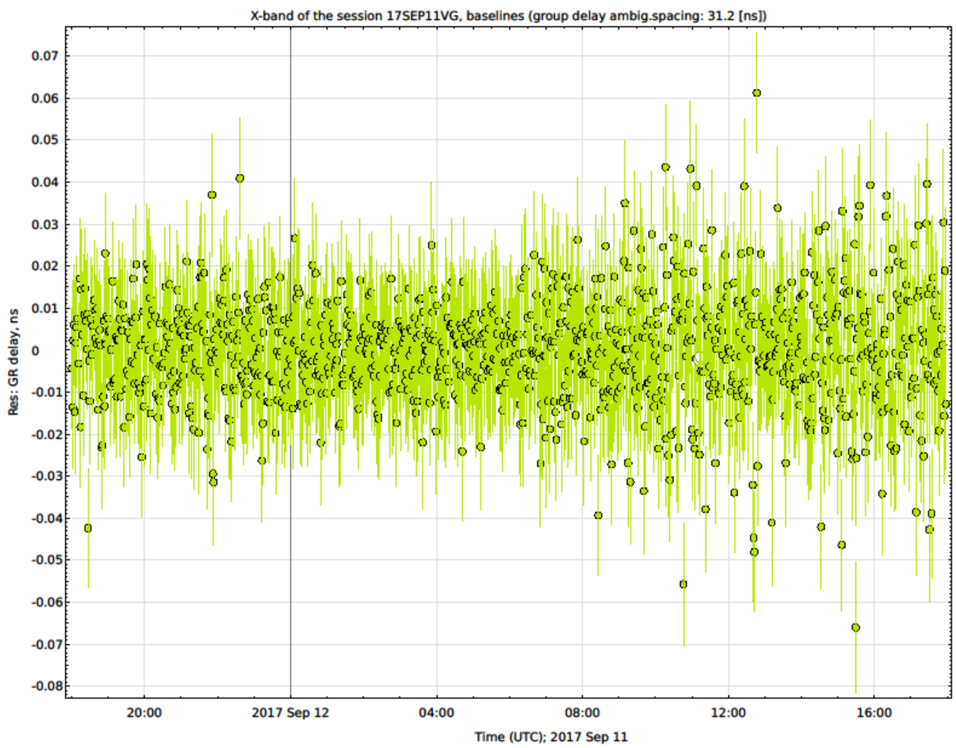

Figure 4. PFDR (reweighted) vs time

Summary

1. When the dewar at GGAO warmed up due to a helium leak, the total system temperatures increased to ~170 K for Bands A-C and to 340 K for Band D.

2. The loss of SNR for the IXY amplitude (combined bands and polarizations) was a factor of approximately 0.5, consistent with the average system temperature increase over the four bands.

3. There was almost no loss of data for the GGAO-Westford baseline because of the conservative scheduling practice that utilized both a high minimum SNR of approximately 40 and a minimum scan length of 30 seconds.

4. The system temperature began rising sharply as soon as the helium leak occurred. The maximum value was reached in about six hours.

5. Before the scheduling parameters are changed to increase the temporal density of observations, either by reducing the minimum scan length or minimum SNR, thought should be given to the impact of a warming receiver.

6. For the current scheduling algorithm and isolated 24-hour sessions, the recommendation for action if the dewar begins to warm is to continue observing until the end of the session, then correct the problem as soon as possible.

7. For the CONT sessions, my recommendation is, if the problem occurs before the last 24 hours, stop observing as soon as the problem is detected and assess the possibility of repair. Further action will depend on the assessment of the probability of repair time. If the assessed repair time is long compared to the end

of the CONT, resume observing. Also, resume observing while waiting for parts. (These recommendations should be discussed more generally.)

Appendix

Extracting Tsys data from the multicast data:

login to the Field System at the station.

For GGAO:
```
ssh oper@206.196.178.59
pwd …
cd ../log
scp -pr vt7254gs_full.log aen@franklin.haystack.mit.edu:/common/VGOS/vt7254
logout
```

On franklin:/common/VGOS/vt7254:

```
date;grep  'tsys/  08b0'  vt7254gs_full.log|awk  -F  ','  '{print  $1,  $2}'> vt7254_tsys_08b0.txt0;date
sed 's/$$$$$$/    0/' vt7254_tsys_08b0.txt0 > vt7254_tsys_08b0.txt
```

secureCRT `vt7254_tsys_08b0.txt` to directory accessible to matlab
(e.g. aen_DELL: `c:\aa\Ivs\VGOS\vt7\vt7254[3618]`

```
matlab:
cd c:\aa\Ivs\VGOS\vt7\vt7254[3618]
plot_tsys_from_multicast_GGAO.m
run
enlarge figure
copy plot-save lines from .m file to command window and execute

repeat for Westford: plot_tsys_from_multicast_Westford.m
```

Supplemental information

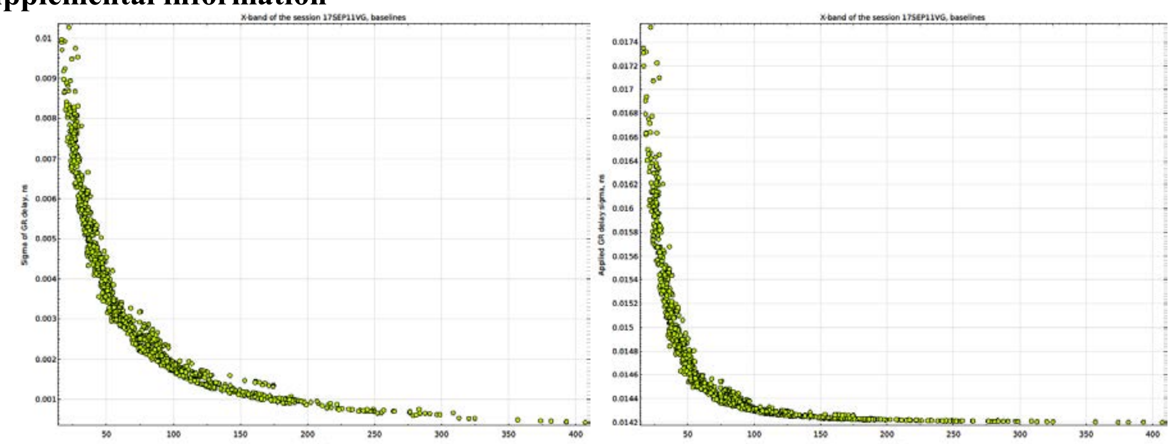

Figure X.   Group delay uncertainty vs SNR. Left: un-reweighted.

Right: reweighted. Note difference in vertical scale