

**CALIFORNIA INSTITUTE OF TECHNOLOGY**  
**PASADENA, CALIFORNIA 91125**  
**January 16, 2008**

To: MWA-LFD Collaboration  
From: Judd D. Bowman  
Subject: Analysis of Drift Scans From 32T-X2

## **1. Introduction**

The second expedition (X2) to Boolardy to work on the 32T system focused on testing two new pieces of the signal path with one tile: the newly redesigned beamformer, and a prototype receiver system. This full system was used to acquire a zenith drift scan for nearly 24 hours in order to test the effects on the system temperature of the new analog components. In addition, a separate 20-hour zenith drift scan was acquired by replacing the prototype receiver system with the Acqiris spectrometer. This configuration also tested the contribution of the new beamformer to the system temperature, but while providing a configuration similar to that used in X1 (which also used the Acqiris spectrometer).

In this document, I will present the derived system temperature values from the Acqiris measurement configurations. The method of deriving the system temperatures used here is identical to that used in X1 (see mwa-lfd memo: Analysis of Drift Scans From 32T-X1 and Characterization of System Temperature). In particular, a canonical model of the antenna tile is used that does not take into account interactions between the dipole elements, and the sky model is simply based on a power law scaling of the Haslam et al. (1982) map. Future drift scan analyses will utilize more accurate antenna models, as well as the improved method of Angelica de Oliveira Costa (<http://space.mit.edu/home/angelica/gsm/>) for interpolating sky maps to the observed frequencies.

Unfortunately, the utility of the new drift scans from X2 is somewhat compromised due to the (unavoidable) timing of the measurements. The measurements were acquired between December 16 and 18, 2007 (UTC). During mid-December, the sun and Galactic center transit at nearly the same time. Thus, the amplitude of primary peak in the drift scans, typically due to the Galactic center transiting alone, is due during this period to the combined Galactic and solar flux. This makes it difficult to separate the two contributions (assuming the flux of the sun must be fit and is not known ahead of time) and to produce an accurate estimate of the gain and system temperature of the instrument.

The data files for the full tile-beamformer-receiver system were provided by Anish Roshi (see <http://www.rri.res.in/rrimwa/X2/X2DRdriftscan/>). The data for the Acqiris measurements were provided Jamie Stevens (see [http://www-ra.phys.utas.edu.au/X2\\_DATA/](http://www-ra.phys.utas.edu.au/X2_DATA/)).

For the Acqiris data, the time stamps in the data file were found to be approximately 12 minutes behind the true time (based on aligning the measured and modeled drift scans by eye). The time stamps were corrected before processing the data.

Figures 1 through 6 show the results of the Acqiris drift scans. Only the measurements labeled as polarization 1 in the data files are shown in this document because those labeled as polarization 2 appeared to be noisier and gave less robust (but similar) constraints. It is not known at this time whether polarization 1 was connected to the north-south or east-west aligned dipoles. For this analysis, I assumed that polarization 1 was connected to the north-south dipoles, as it was in X1.

## 2. Attempting to Account for the Solar Flux

Since the contribution of the solar flux was a significant complication in these data, three different assumptions for the solar flux were treated in the analysis:

- Treatment #1: The system temperature is derived by allowing the solar contribution to be fit as a (frequency-dependent) parameter in the model (as it was for the X1 drift scans). The results of this treatment are shown in Figure 1.
- Treatment #2: The system temperature is derived assuming that the solar flux is a frequency-constant  $S = 10^5$  Jy. The results of this treatment are shown in Figure 2.
- Treatment #3: The system temperature is derived assuming no solar flux ( $S = 0$  Jy). The results of this treatment are shown in Figure 3.

The  $T_{\text{sys}}$  values from the three treatments span a significant range, from bad (in Figure 2) to acceptable (in Figure 1) to too good to be true (in Figure 3). Which is correct (or at least most likely)?

It turns out that increasing the prescribed flux of a fixed solar contribution in our model causes a systematic lowering of the gain estimate of the instrument and a systematic elevation of the  $T_{\text{sys}}$  estimate. The reason for this is that a drift scan based on only the solar contribution would fall nearly to zero away from peak transit, whereas a drift scan including the Galactic contribution falls only to the cold sky temperature. Thus, when more of the peak is accounted for with the sun, the  $T_{\text{sys}}$  offset must increase to get the baseline (non-transit) values to match the cold sky temperatures. At the same time, the gain must be decreased so that the peak transit value is still fit correctly. So, by setting the solar flux to  $S = 0$  Jy (as in Treatment #3), we can find a constraint on  $T_{\text{sys}}$  guaranteed to be a lower limit. And by setting the solar flux to a large value (such as  $S \geq 10^5$  Jy, as in Treatment #2) we can find an upper limit on  $T_{\text{sys}}$ . Similarly, the inverse is true of the gain.

According to Frank Briggs (cite?), the typical (quiet) solar flux is approximately  $10^5$  Jy at 300 MHz, falling with frequency to about  $10^4$  Jy at 100 MHz. (Note: It is important to stress that

these typical fluxes are for a quiet sun and could be much larger if there is any solar activity.) Nevertheless, I have used  $10^5$  Jy (regardless of frequency) as a fixed solar flux level to set a reasonable upper limit on  $T_{\text{sys}}$ . This is justified based on the derived solar fluxes from X1 (see [mwa-lfd memo #3, Figure 8]). Further confirmation that the true solar flux is below this level over most of our frequency range comes from Figure 4, which displays the derived solar fluxes for Treatment #1 and matches well with X1 values in [mwa-lfd memo #3, Figure 8]. Figures 7 and 8 also illustrate that the derived values of  $T_{\text{sys}}$  and gain from Treatment #1 fall within the bounds set by Treatments #2 and #3.

All of this tends to give me more confidence than I originally had in the estimates resulting from Treatment #1 (Figure 1). Whether this is sufficient to determine if the new beamformer used in X2 has a better (or worse) impact on the system temperature than the Early Deployment-era beamformer used in X1 is difficult to say and I leave it to others to decide.

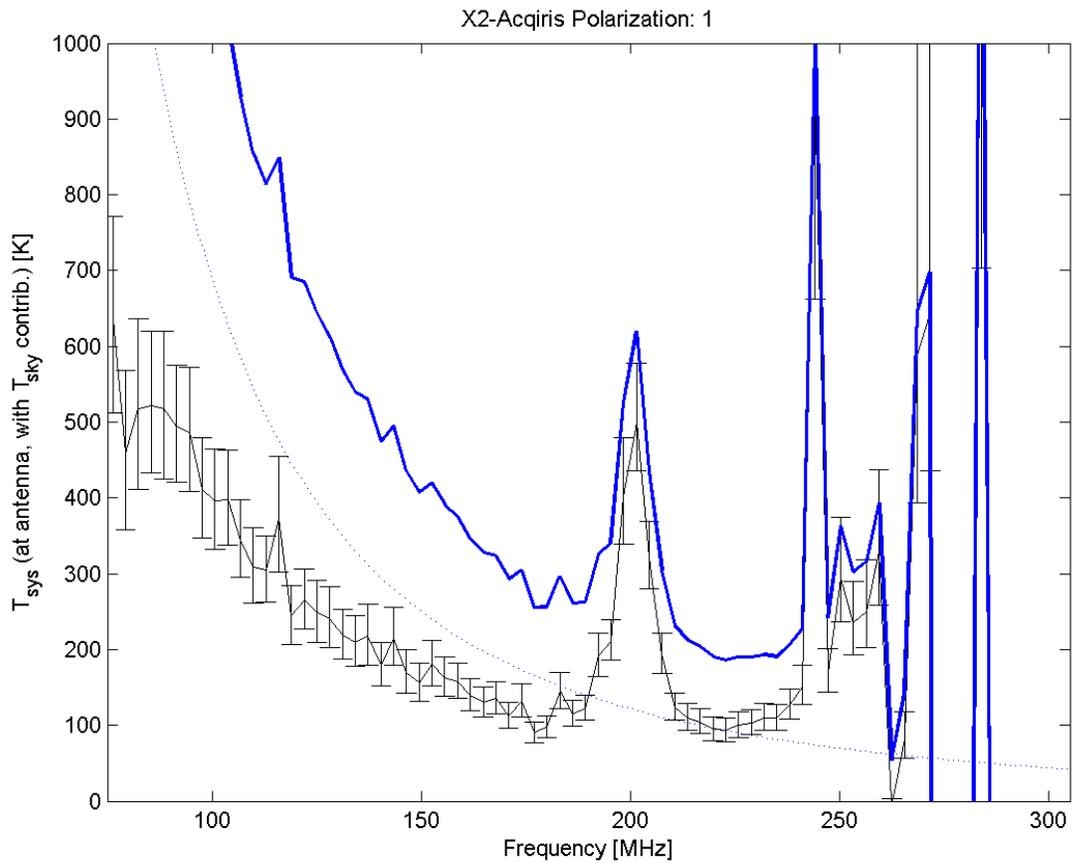


Figure 1.  $T_{\text{sys}}$  derived from polarization 1 of the drift scan acquired with Acqiris spectrometer during X2, December 17-18, 2007 (UTC). The solid black line with error bars is the “receiver” component of the system temperature derived from the measurements. The error bars give the 95% confidence interval. The dotted blue line is an estimate of a cold sky temperature according to  $T_{\text{sky}} = 250 \text{ K} * (f / 150 \text{ MHz})^{-2.5}$ . The solid blue line is the sum of the receiver and sky temperatures and provides an estimate of the full system temperature seen during an observation targeting a cold part of the sky. **For this plot, the solar flux was fit as an independent model parameter (see Figure 4 for the derived solar flux values).**

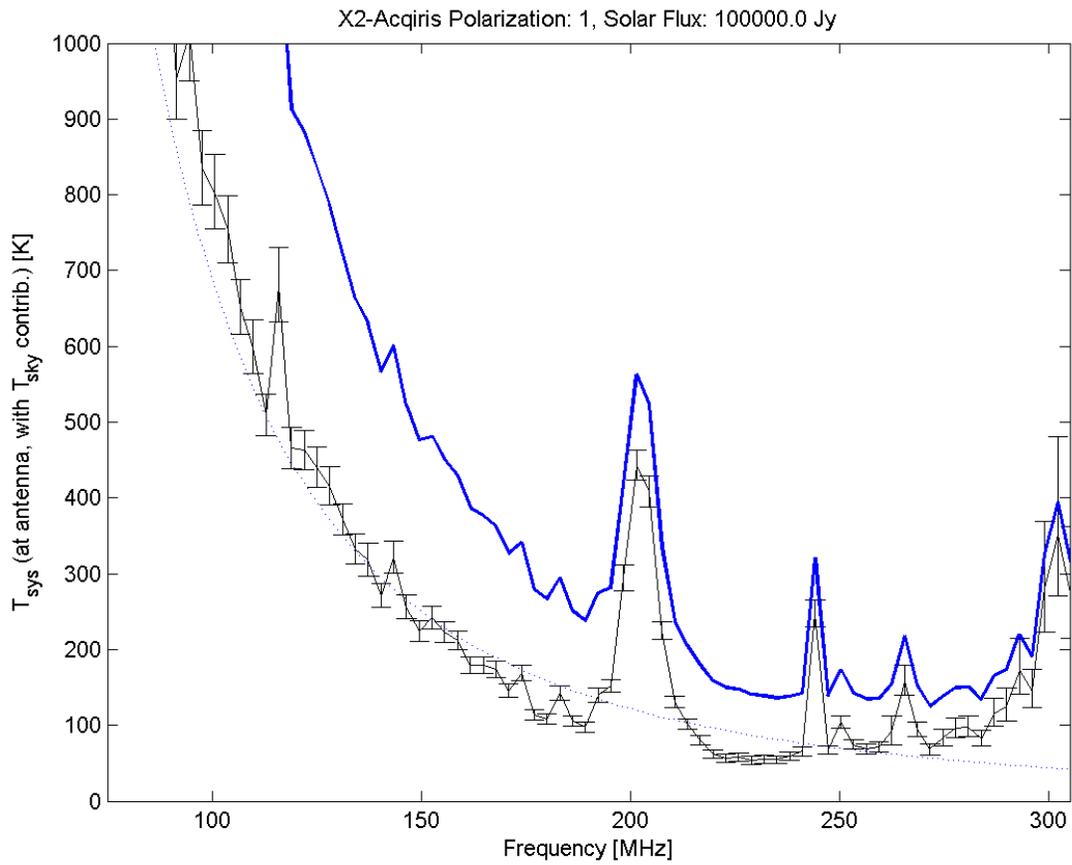


Figure 2. Same as Figure 1 except, **for this plot, the solar flux was constrained to  $10^5$  Jy (independent of frequency)**. The error bars are smaller here than in Figure 1 because there is no degeneracy between the (now-fixed) solar flux and the Galactic center flux. Also, the error bars do not account for model error.

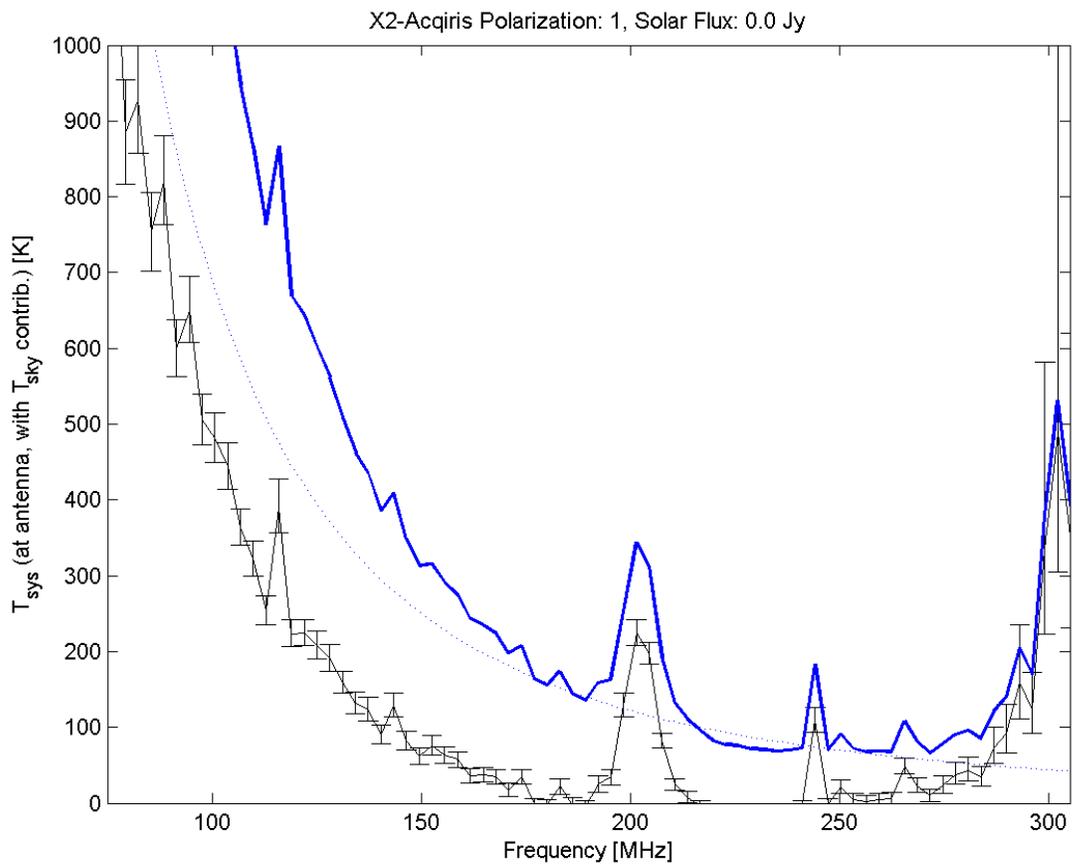


Figure 3. Same as Figure 2 except, **for this plot, the solar flux was constrained to zero.**

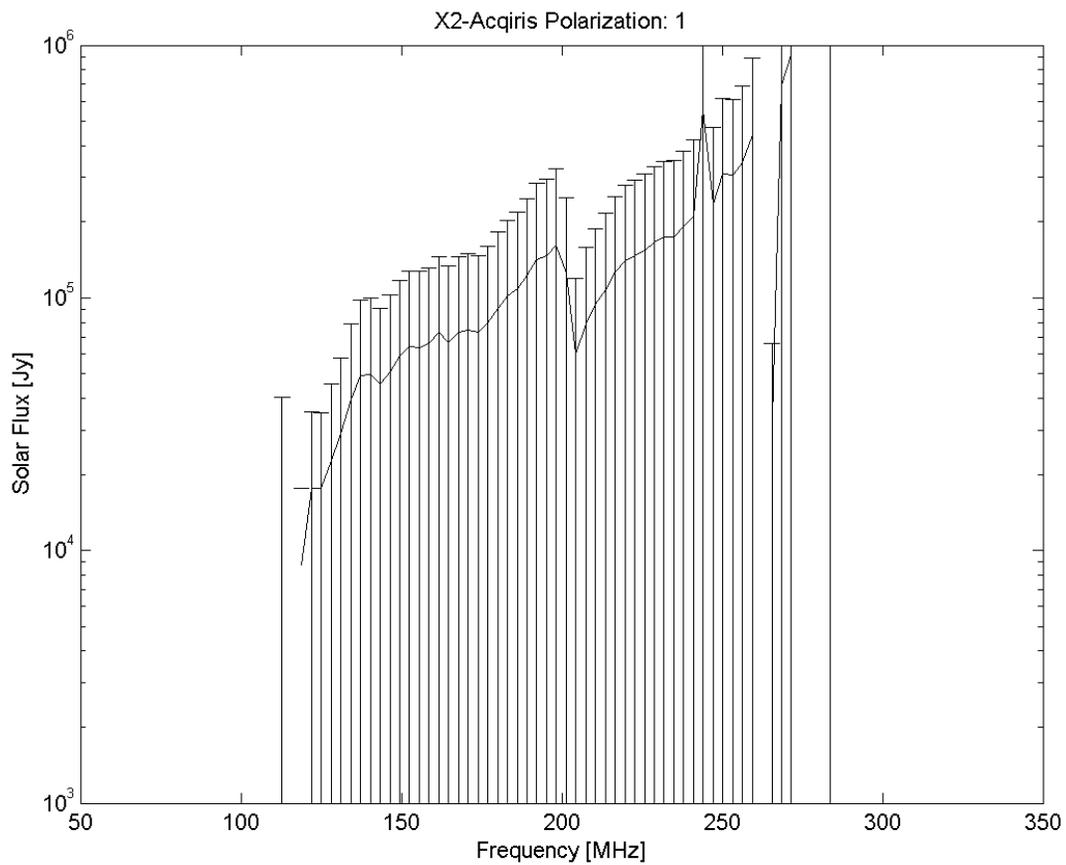


Figure 4. The derived solar flux values associated with the system temperatures shown in Figure 1. These values agree remarkably well with those found in X1 ([mwa-lfd memo #3, Figure 8]), when the sun transited a few hours before the Galactic center and the solar flux was, therefore, well constrained.

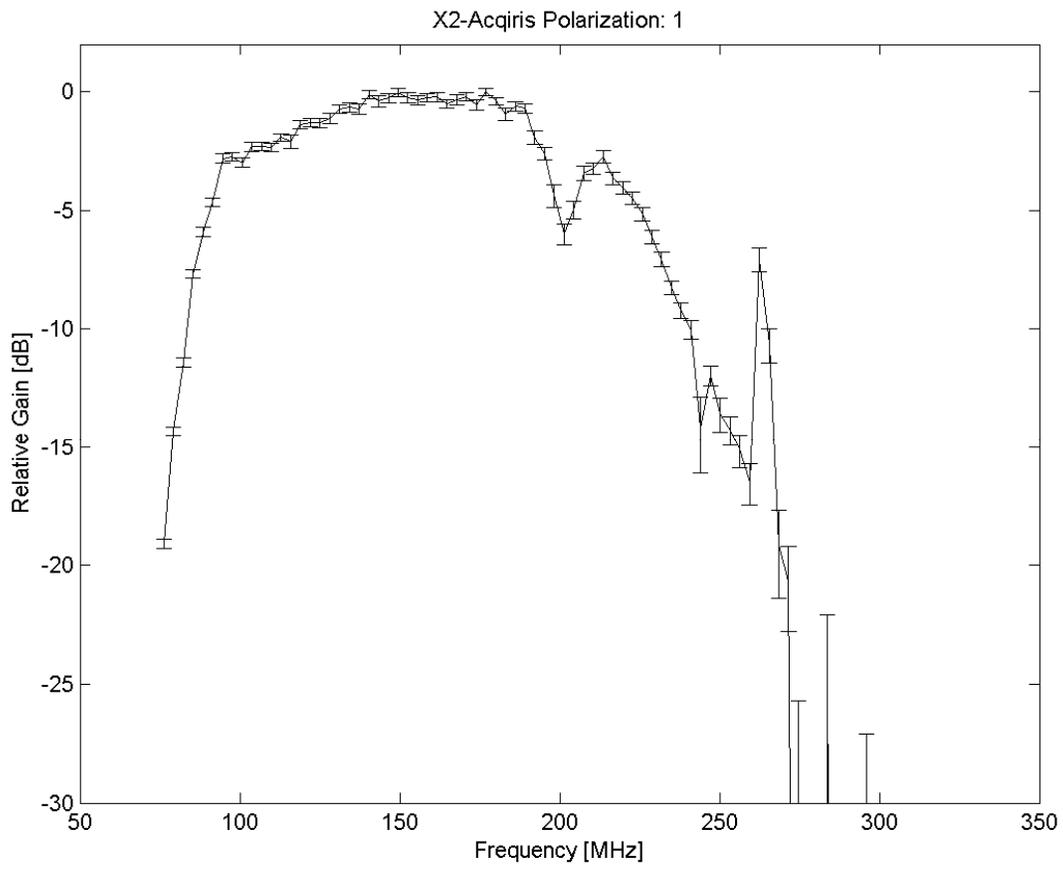


Figure 5. The relative gain values associated with the system temperatures shown in Figure 1.

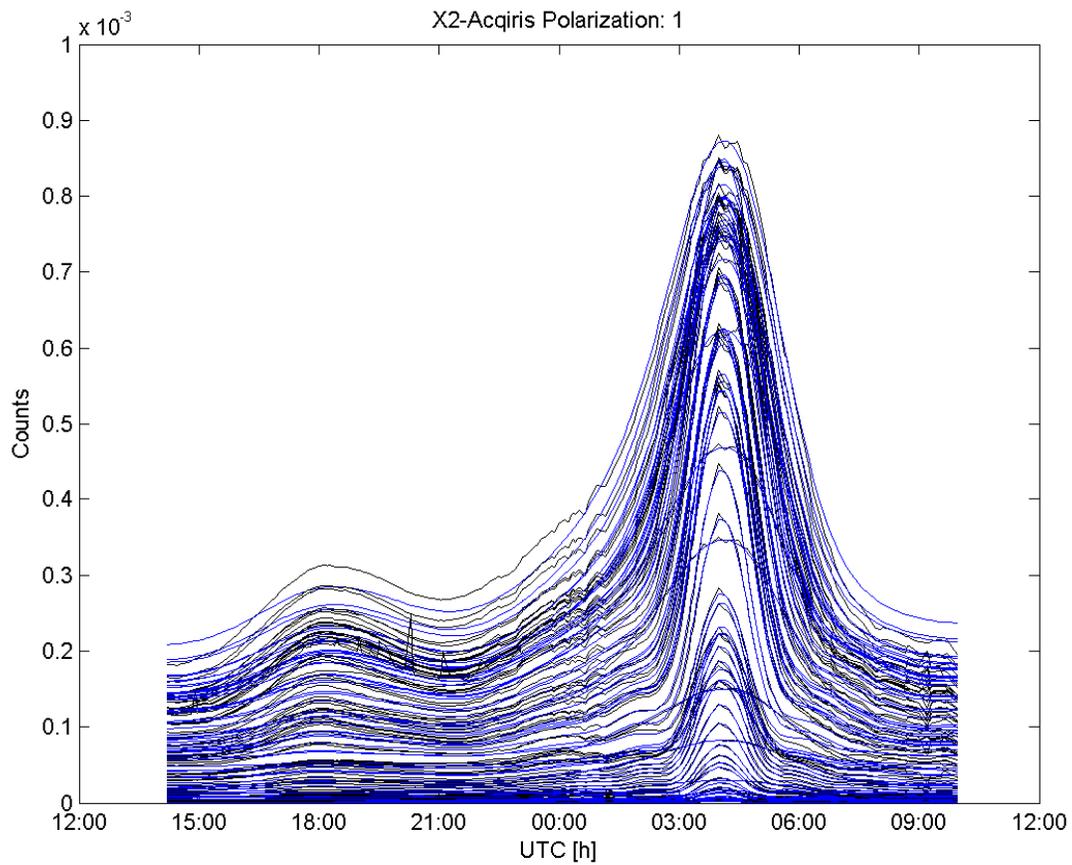


Figure 6. The measured (black) and modeled (blue) drift scans associated with the system temperatures shown in Figure 1. Many frequencies are plotted between roughly 75 and 300 MHz in approximately 3 MHz increments. Lower frequencies generally have higher amplitudes. Although not shown, the model fits to the measured drift scans for Treatments #2 and #3 appear very similar (they aren't obviously any worse [or better] than these).

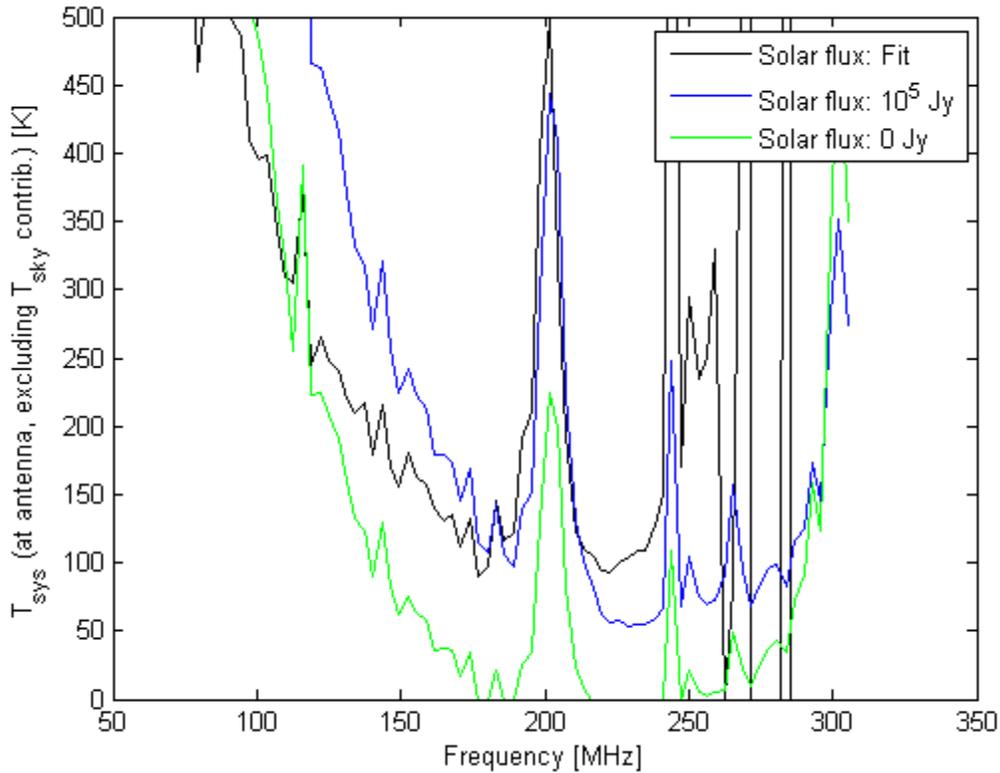


Figure 7. Comparison of system temperatures derived from the three treatments of the solar flux described in the text. Note that assuming no solar flux sets a lower limit for the system temperature, whereas assuming a typical (quiet) solar flux of  $10^5$  Jy still results in a higher estimate of the system temperature than allowing the solar contribution to be fit as an independent parameter in the model. A true upper limit would require setting the solar flux above the typical quiet level, but this appears unnecessary here, especially since  $10^5$  Jy is typical at 300 MHz and  $10^4$  is typical at 100 MHz. Thus, I would assert that this is a fair upper limit. I think that is supported by the “fit” solar flux (see Figure 4) falling being roughly consistent with the trend from  $10^5$  to  $10^4$  Jy as the frequency decreases over the band.

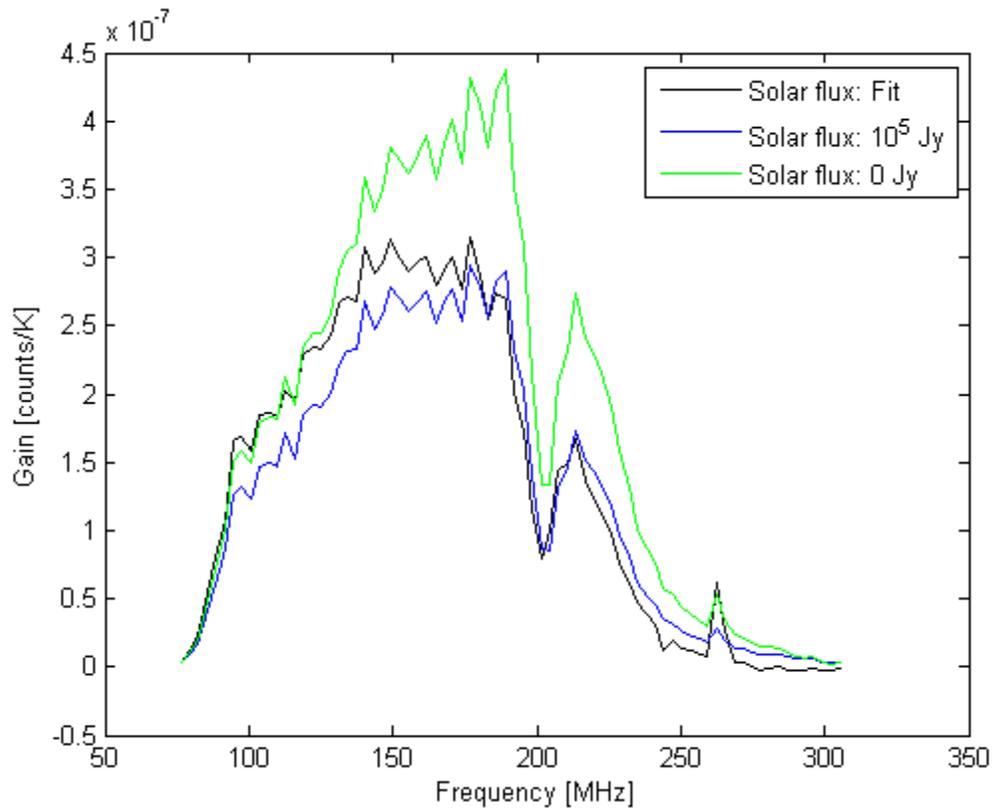


Figure 8. Similar to Figure 7, but showing the difference in absolute gain for the three treatments of the solar flux described in the text. Here, assuming no solar flux results in an upper limit on the absolute gain.

### **3. Drift Scans with Prototype Receiver**

TBD.

### **4. Acknowledgements**

This analysis was supported in many ways by the contributions of Frank Briggs and the X2 field deployment team.

### **5. References**

1. MWA-LFD memorandum #3:  
Analysis of Drift Scans From 32T-X1 and Characterization of System Temperature  
<http://mwa-lfd.haystack.mit.edu/knowledgetree/view.php?fDocumentId=651>
2. C. G. T. Haslam, H. Stoffel, C. J. Salter, and W. E. Wilson. A 408 MHz all-sky continuum survey. II - The atlas of contour maps. *A&AS*, 47:1 — +, January 1982.