NOISE TRENDS IN HERA COMMISSIONING DATA

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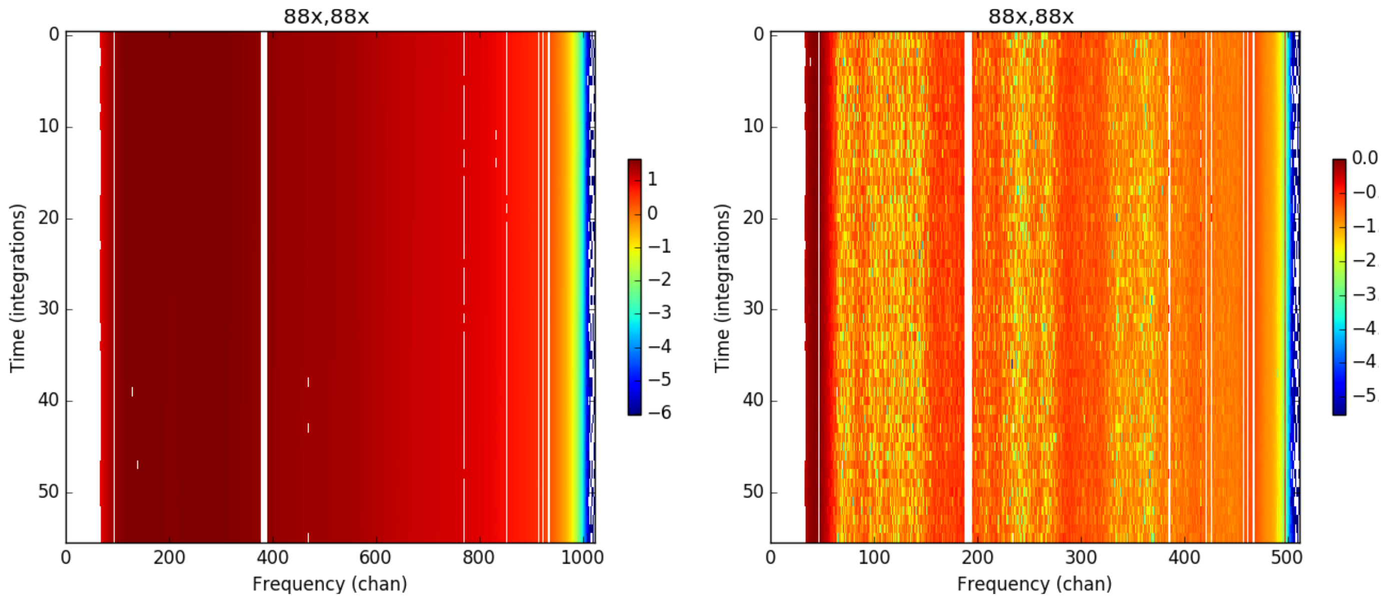
ABSTRACT

This investigation aims to demonstrate the sensitivity of the HERA19 configuration to basic astronomical signals. Specifically, we demonstrate that data from the HERA Internal Data Release 1 (collected June 8, 2016, Jd 2457548) shows anticipated peaks in statistical noise corresponding to the transit of the galactic plane. Because the 19-element configuration has limited imaging ability, statistical approaches such as this are necessary to confirm that the equipment is behaving as expected.

Figure 1: Frequency Differencing for Antenna 88 Auto-Correlation



(a) Raw auto-correlation for antenna 88, following RFI flagging.

(b) Frequency-differenced auto-correlation for antenna 88. *Note: Channel numbering is restarted during this step, but the frequencies of the original data are preserved.*

1. THEORY

Noise from an astronomical signal can be quantified by subtracting visibilities that neighbor each other in frequency or time (Thompson *et al.* 2001). This method is based on the assumption that astronomical signals change slowly in time and vary smoothly in frequency, such that the difference of neighboring visibilities is predominantly noise. At the frequencies HERA observes, it is reasonable to assume that observed noise is dominantly sky, rather than receiver, noise.

This analysis targeted two astronomical signals that should be detectable by the HERA19 array: the peak in overall power associated with the transit of the galactic plane, and the frequency spectrum of overall power.

2. METHODS

HERA Internal Data Release 1 contains a total of 4,020 10.74-s integrations for 1024 frequency channels. The total bandwidth is 100 MHz, or 97.7 kHz per channel. The data were collected on June 8, 2016 (Jd 2457548) beginning at 16:00:23.4 UTC.

Data were initially flagged for RFI using AIPY tools (see Figure 1a). The full data set was then split into "odd" and "even" samples along both time and frequency axis by taking every other sample from the data array (and adjusting all other indexing arrays accordingly). The odd and even data arrays were then subtracted to obtain "differenced" files (see Figure 1b).

The folder of differenced data was loaded into Python using UVCache.py - a tool developed to facilitate seamless access of large datasets spread over several Miriad files without needing to import all of them simultaneously as UVData objects. RMS values were calculated for several time and frequency windows, and for both time- and frequency-differenced files.

Figure 2: Peak in RMS Noise near LST 17:40 with 10 MHz x 20 min RMS window on frequency-differenced file

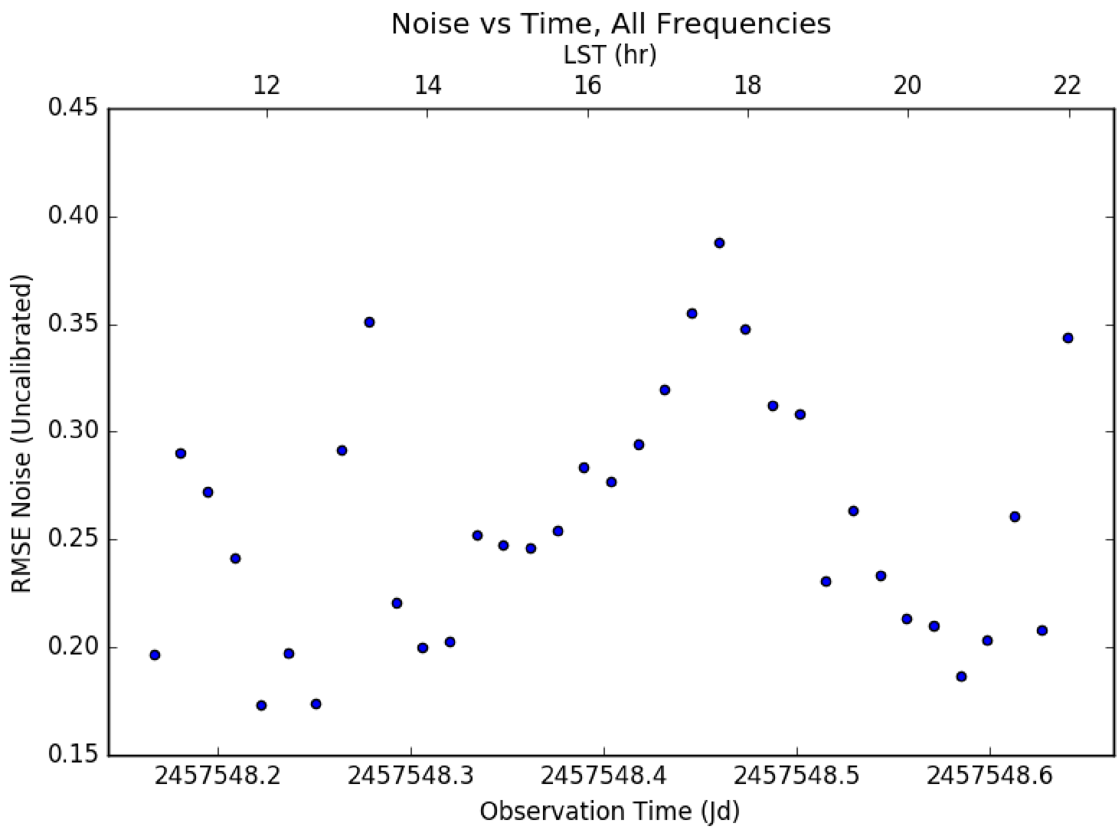
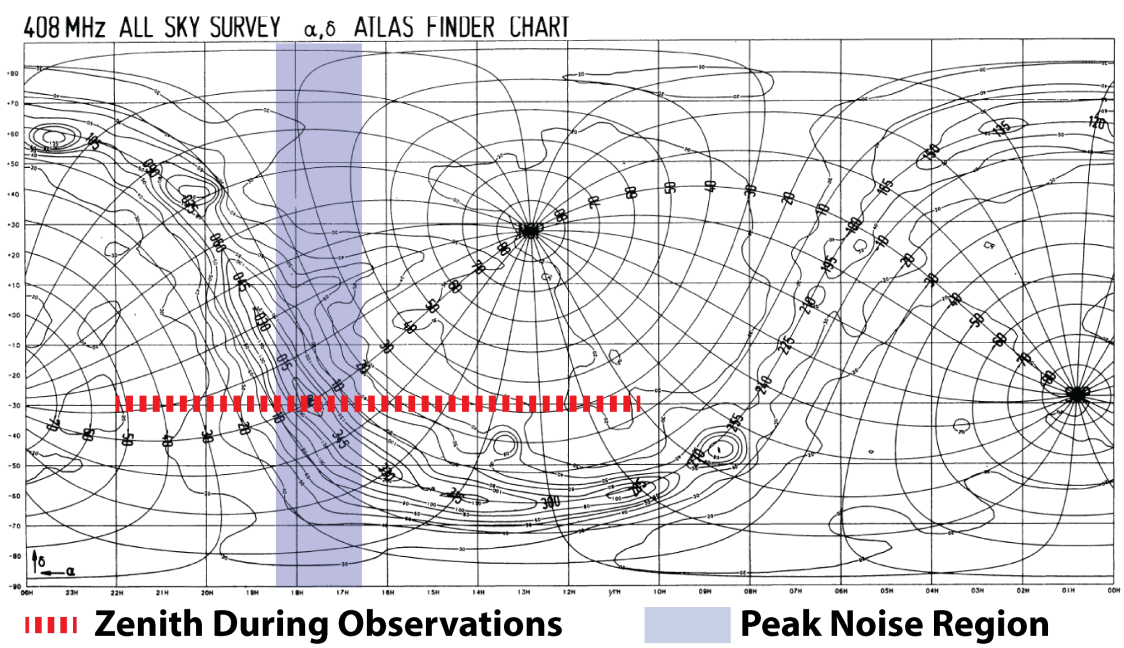


Figure 3: Radio intensity map showing transit of galactic plane corresponding with peak in RMS noise. Map from Haslam *et al.* (1982)



The Python code used for this analysis is available at http://github.com/PhilipMathieu/noise.py/. The current version at the time of publication of this memo is available as a "release."

3. RESULTS

Appendix A contains plots for all RMS window dimensions and both frequency- and time-differencing. All plots show mean over all baselines, including both cross and auto correlations.

The most promising results come from the frequency-differenced files. These show a distinct peak in RMS noise around LST 17:40 (see Figure 2). This timing of this peak corresponds to the transit of the galactic plane (see Figure 3).

This peak is visible to varying degrees in all frequency-differenced data, but not in any time-differenced data. One possible explanation for this is the integration length, which may be too long for the differencing technique to be effective.

None of the data show any notable frequency structure. We would typically expect to see sky noise levels decreasing with increasing frequency. The noise-vs-frequency plots show no evidence of this trend; if anything, they simply highlight the localization of noise in a handful of particularly noisy bands.

4. CONCLUSIONS

The result of this analysis is a promising indicator that the HERA19 configuration is behaving as expected. The presence of noise peaks timed with the transit of the galactic plane matches expected overall intensity behavior. However, the concentration of this noise in a handful of specific frequencies suggests that RFI flagging may be failing to mask some non-sky noise sources. Further investigation is required, on additional data if possible, to more comprehensively confirm expected performance. Eventually, this technique could be combined with absolute antenna gains to calculate the system temperature and its time and frequency structure.

REFERENCES

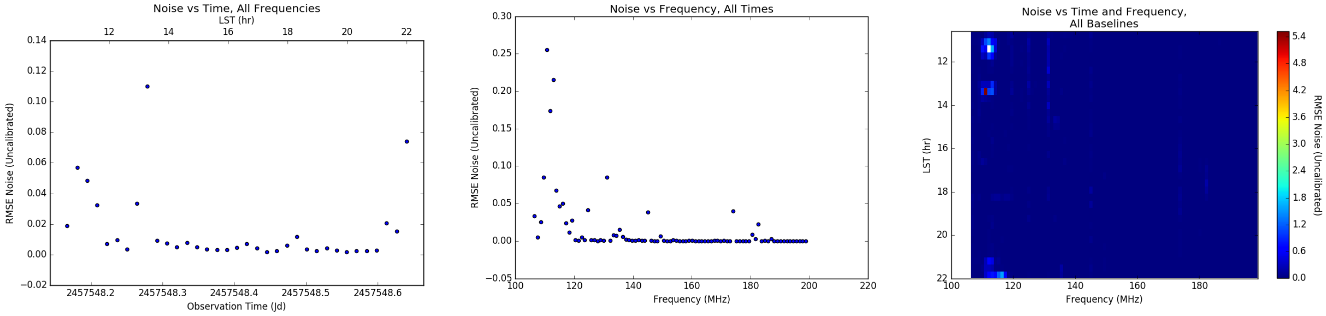
A. Richard Thompson, James M. Moran, and George W. Swanson, Jr. *Interferometry and Synthesis in Radio Astronomy*, 2nd Ed. 2001.

C.G.T. Haslam, C.J. Salter, H. Stoffel, and W.E. Wilson. *A 408 MHz All-Sky Continuum Survey. II. The Atlas of Contour Maps*. 1982.

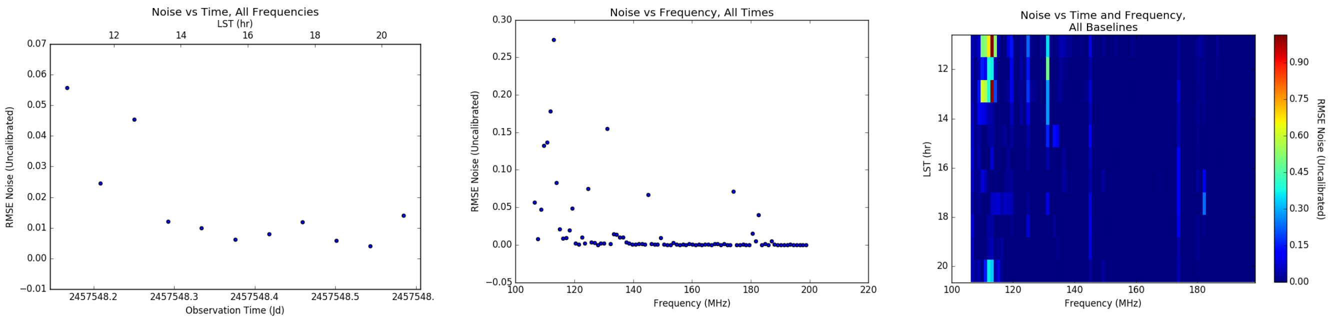
APPENDIX

A. CHARACTERISTIC PLOTS

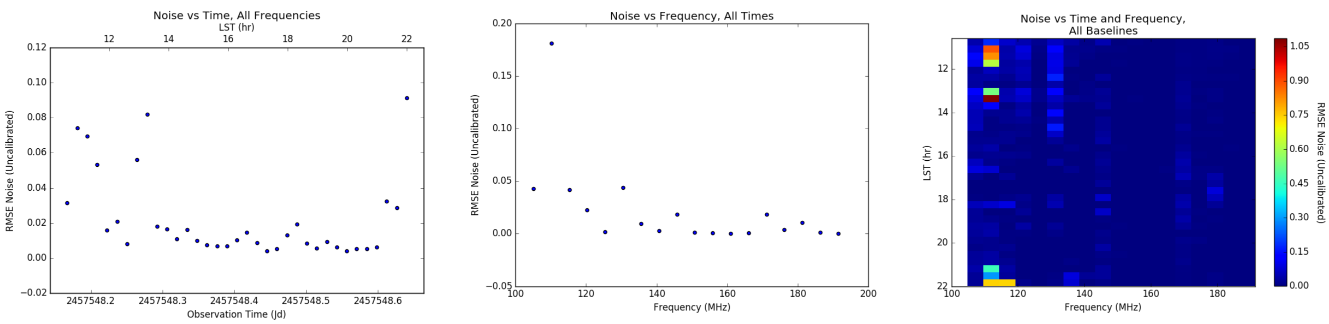
1 MHz x 20 min RMS Window, Time-Differenced



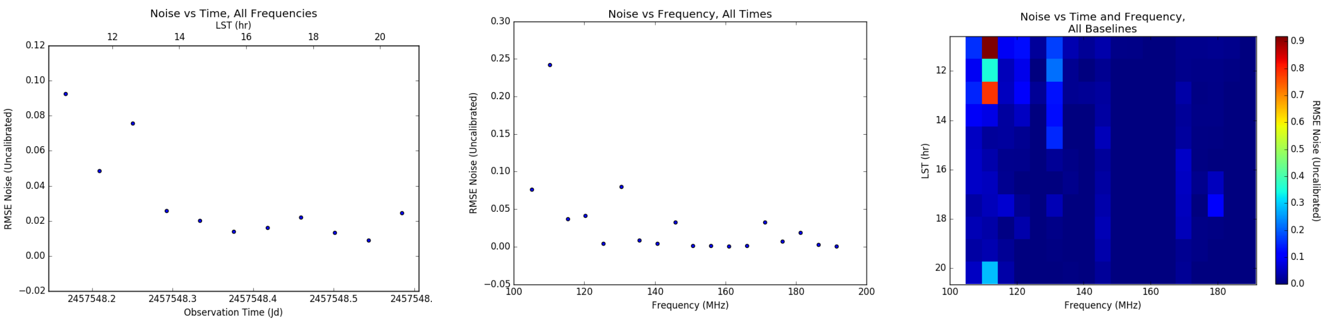
1 MHz x 60 min RMS Window, Time-Differenced



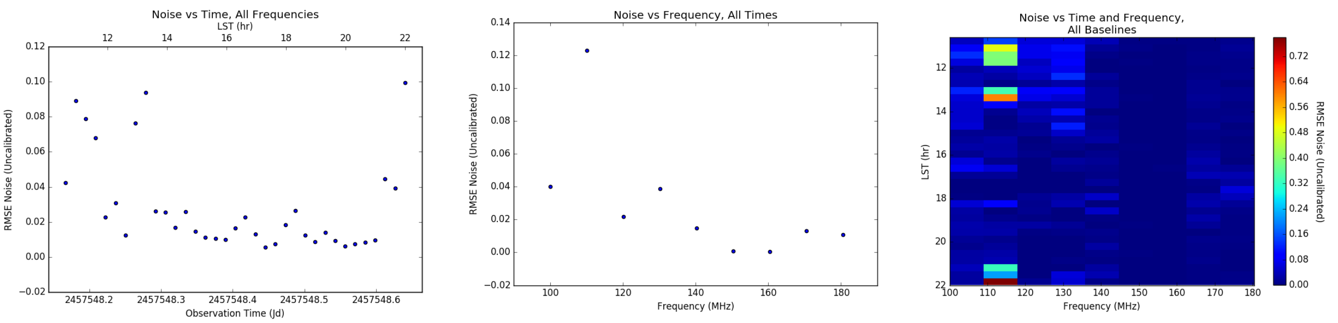
5 MHz x 20 min RMS Window, Time-Differenced



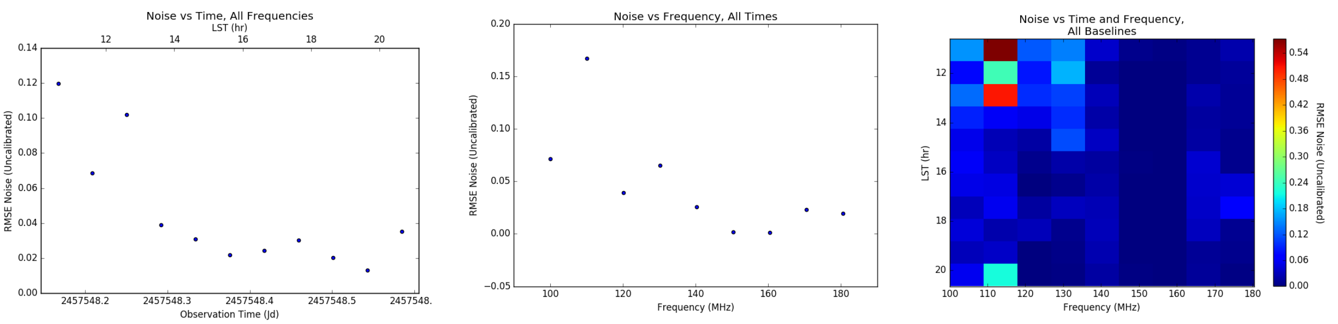
5 MHz x 60 min RMS Window, Time-Differenced



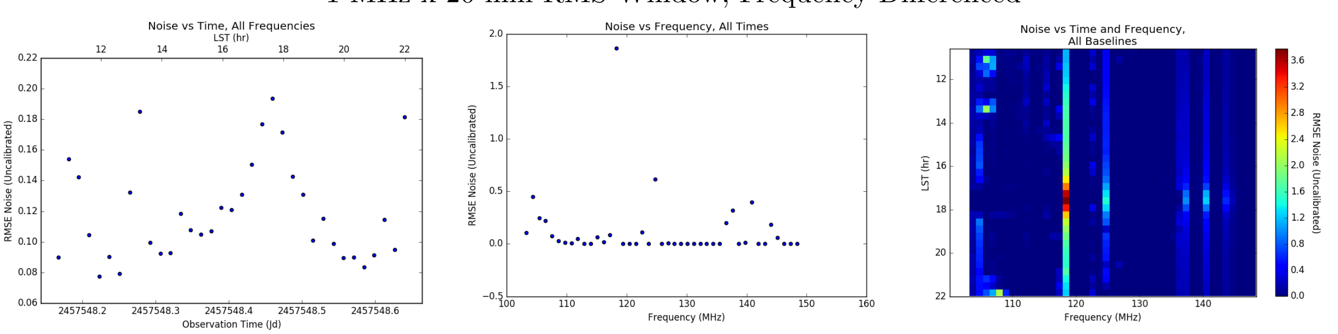
10 MHz x 20 min RMS Window, Time-Differenced



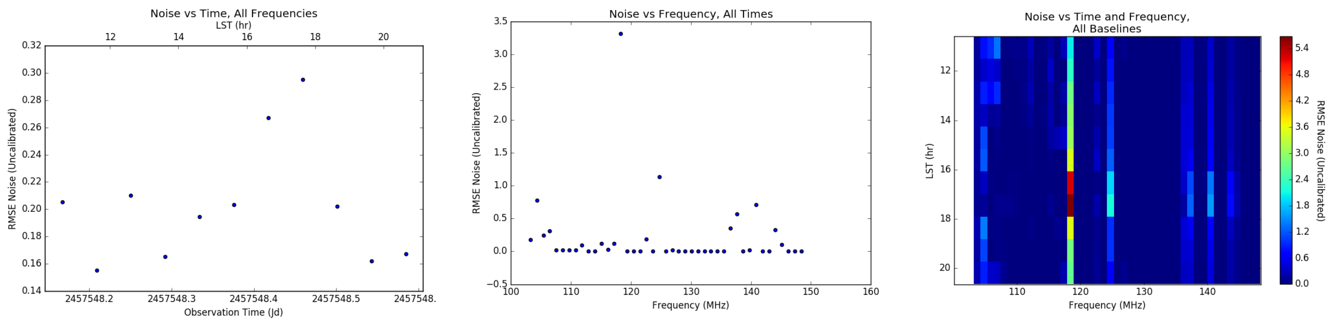
10 MHz x 60 min RMS Window, Time-Differenced



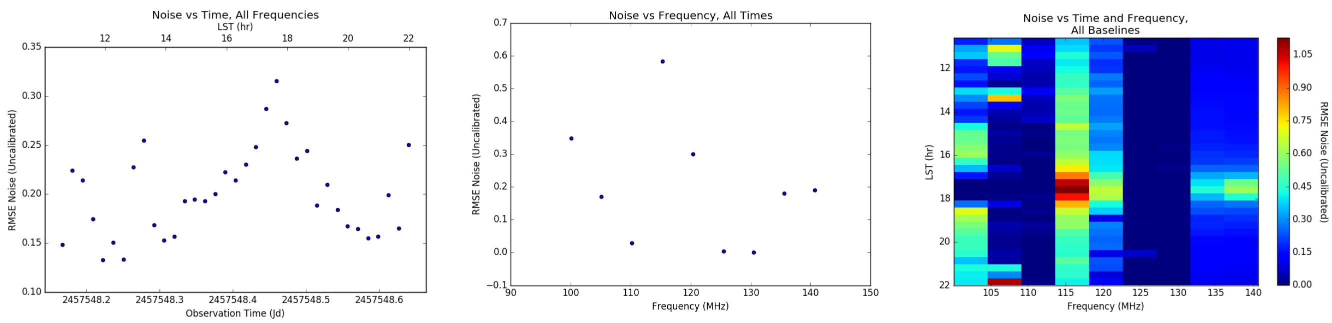
1 MHz x 20 min RMS Window, Frequency-Differenced



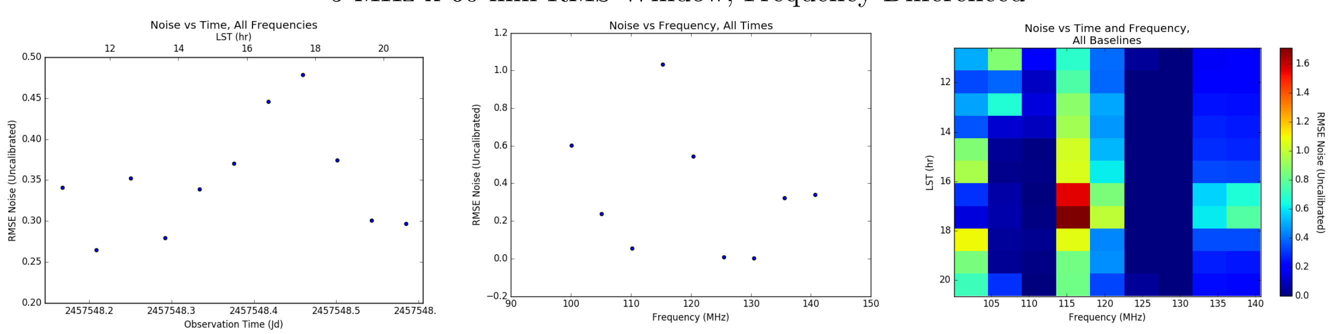
1 MHz x 60 min RMS Window, Frequency-Differenced



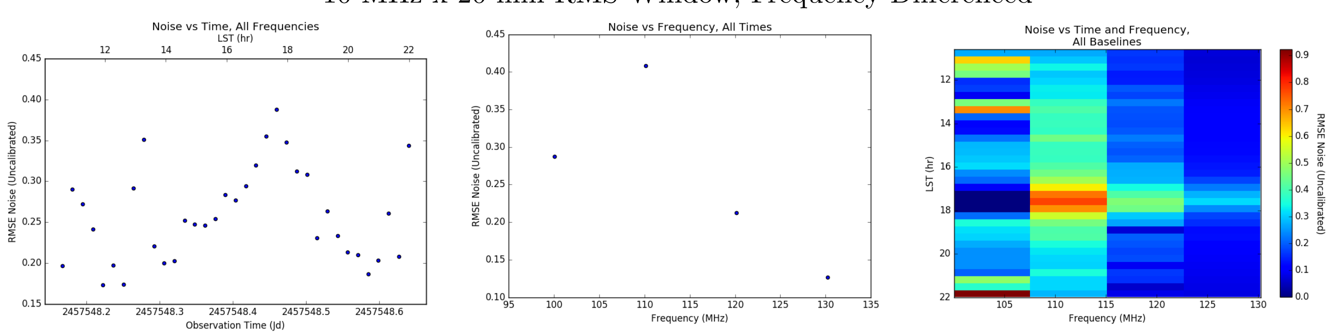
5 MHz x 20 min RMS Window, Frequency-Differenced



5 MHz x 60 min RMS Window, Frequency-Differenced



10 MHz x 20 min RMS Window, Frequency-Differenced



10 MHz x 60 min RMS Window, Frequency-Differenced