

**MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886**

April 29, 2014

*Telephone: 781-981-5400
Fax: 781-981-0590*

To: EDGES Group

From: Alan E.E. Rogers

Subject: Spectral effects of LNA box on antenna beam.

The current EDGES-2 installation at Boolardy has the LNA box (17"×10" ×5" – see memo #123) under the antenna panels above the ground plane. While initial simulations suggested that the effect on the antenna beam would be small the calibrated spectra have the large variations in the spectra which repeat with sidereal time shown in Figure 1. These spectra are the residuals to a 2 parameter least squares fit to the scale and spectral index. The data at 2014:20:11:04 is at the transit of the Galactic center. The largest spectral deviations are above 170 MHz on either side of the Galactic transit. The data at 108:13:15 has RFI and the data at 108:06:10 has a contribution from the Sun. The Sun is below the horizon from 09:40 to 22:40 Figure 2 shows the same data corrected for the antenna beam using a model from FEKO convolved with the sky based on the Haslam Survey at 408 MHz with an assumed spectral index of 2.5. The values of spectral index derived from the corrected data range from 2.4 at night rising to about 2.5 3 hours before Galactic transit, peaking to about 2.54 at transit and dropping again about 3 hours after transit. Data from about 02 to 09 hr has not yet been corrected for the temperature of the LNA which rises about 25 °C during this time period because the thermal control is lost due to the high summer temperatures during the day. However, curvature in the spectra between 06 hr and sunset is most likely due to the contribution of the solar flux to the spectrum. Figure 3 shows the repeatability of the residual spectra for days 99 through 113. Digital TV channels 6,7 & 8 are visible on day 109. This was probably due to a temperature inversion that results in the signals travelling long distances by following the Earth's curvature due to the refraction.

The corrections to the spectra, based on the convolution of the beam patterns from FEKO with the sky, are plotted in Figure 4. The correction at Galactic transit is about 40K peak to peak. Most of the correction results in change of the observed spectral index. The largest change in spectral index occurs around Galactic transit and changes the observed spectrum index by about 0.1. The corrections after removal of a change in spectra index are plotted in Figure 5 and Figure 6. Even corrections with the Galactic center below the horizon have significant structure as a result of the LNA box. If a 5 parameter fit is made to the corrections of Figure 6 the rms with the box ranges from 35 to 200 mK whereas without the box the rms is under 1 mK for all the hour angles shown in Figure 6.

The RFI seen in Figures 1 and 2 at 108:13:15 probably comes from the Russian satellite METEOR-M which has a wideband mode centered at 137.9 MHz. Some improvements in the processing have had to be made to exclude data contaminated with this signal.

The FEKO model had the optimum value of the mesh triangle side length of 4.69 cm. For some reason a slightly smaller mesh of 4.68 cm results in beam patterns which are obviously incorrect without any indication of loss of accuracy in the FEKO output messages. Similar tests with

NEC2 produced similar beampattern whose accuracy was smoothly dependent on mesh size without an abrupt change until the meshing was so fine that the equations could not be solved and the program terminated with error messages. The FEKO model used a simple voltage source at the center of a wire between the panels. An approximation of the asymmetric top cap was tried and gave very similar results which did not significantly improve residuals of the fits to the beam corrected spectra.

If the 408 MHz sky map is corrected for the spectral index of the Galaxy using the approximation given in memo #7 there a slight improvement in the corrected spectra. The use of a better sky model and more accurate EM modeling are under study.

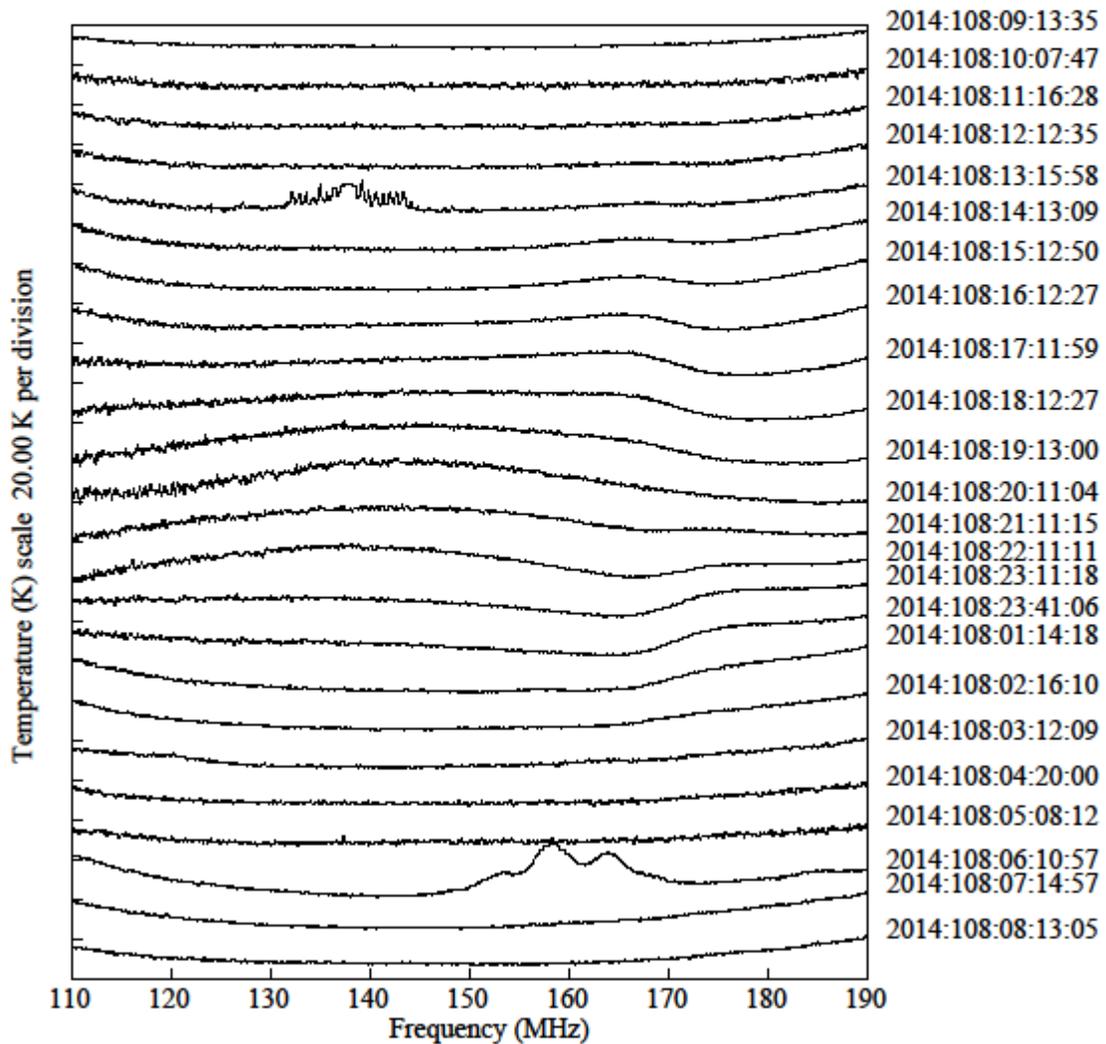


Figure 1. Calibrated EDGES spectra residual to best fit scale and spectral index.

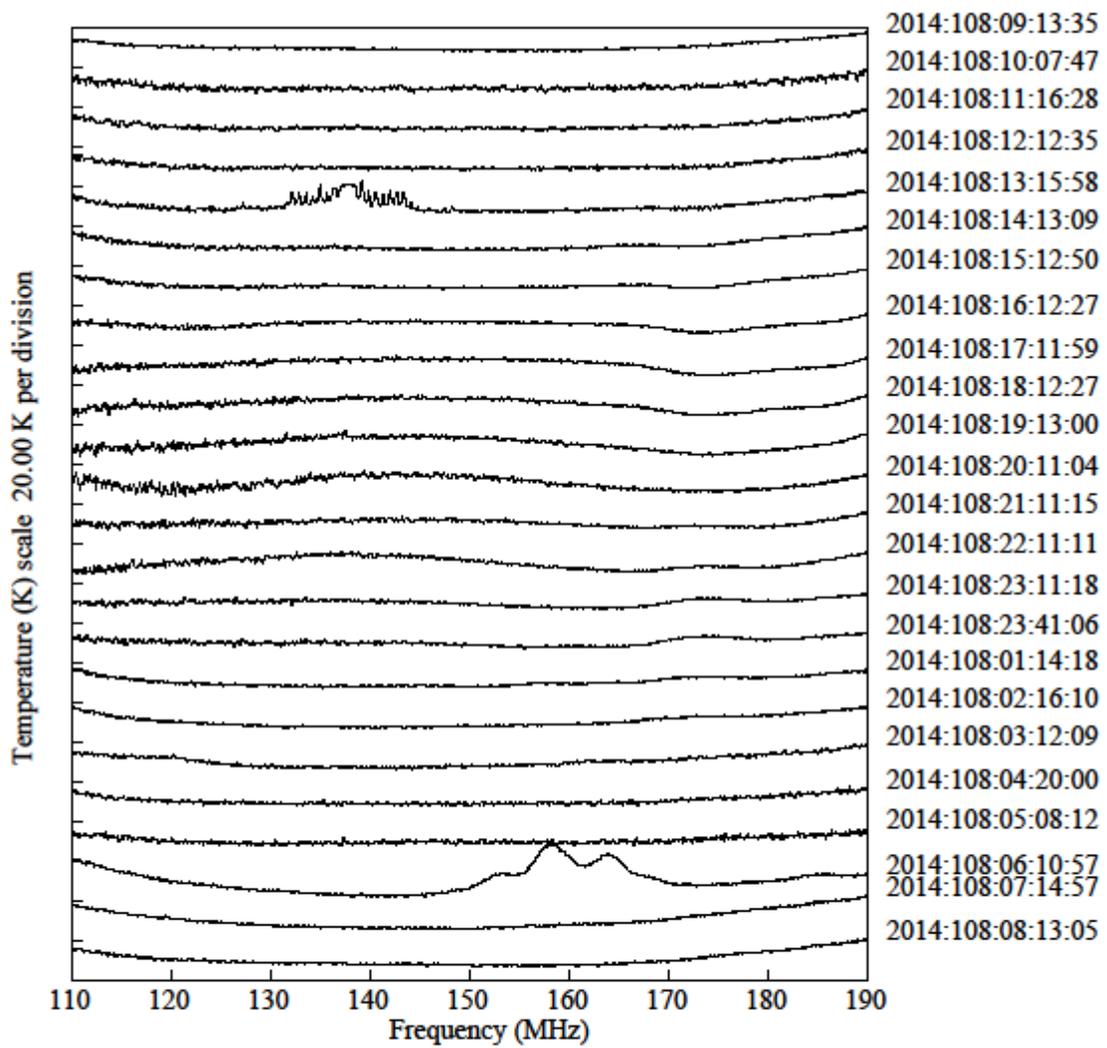


Figure 2. Spectra after correction for antenna beam change with frequency.

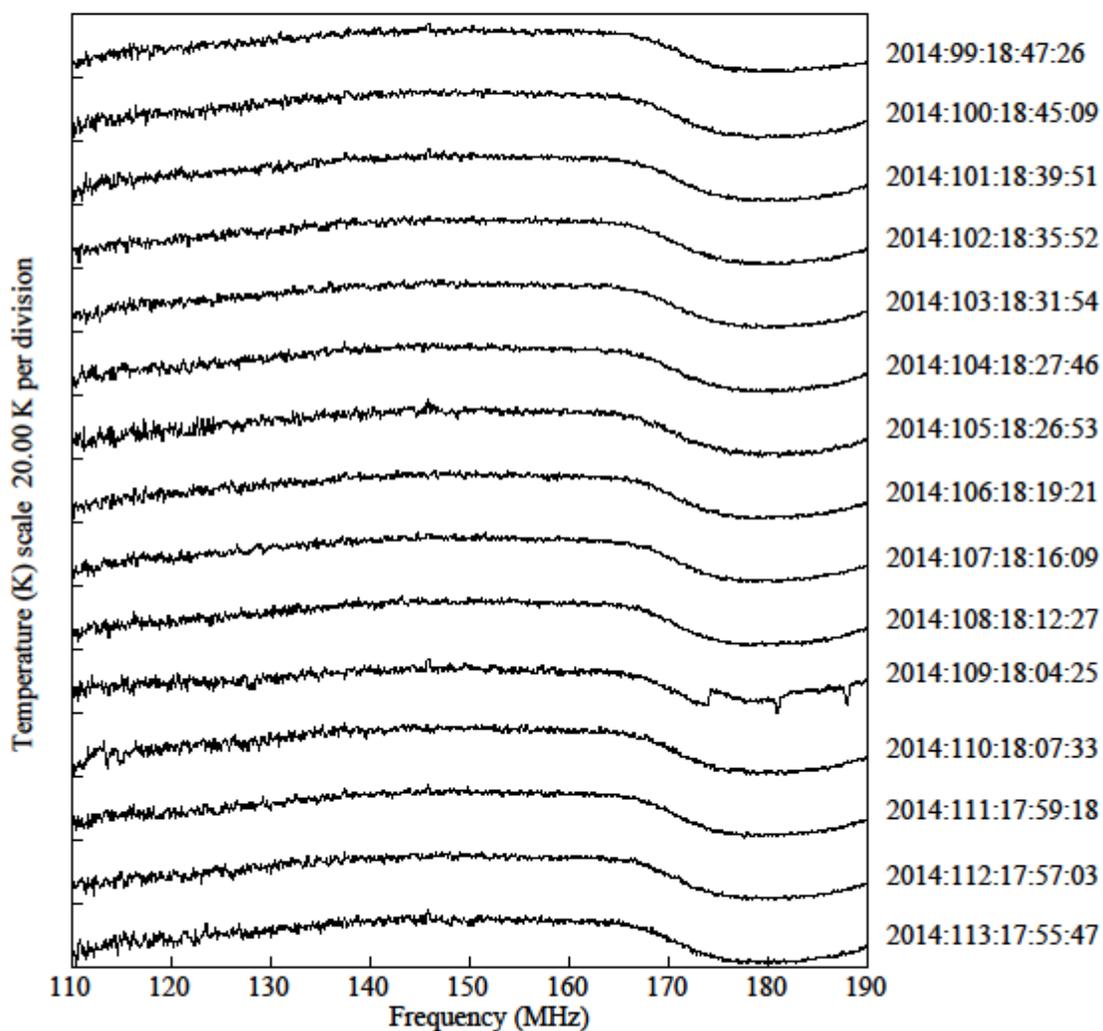


Figure 3. Repeatability of uncorrected spectra on different days 2 hrs before the transit of the Galactic center.

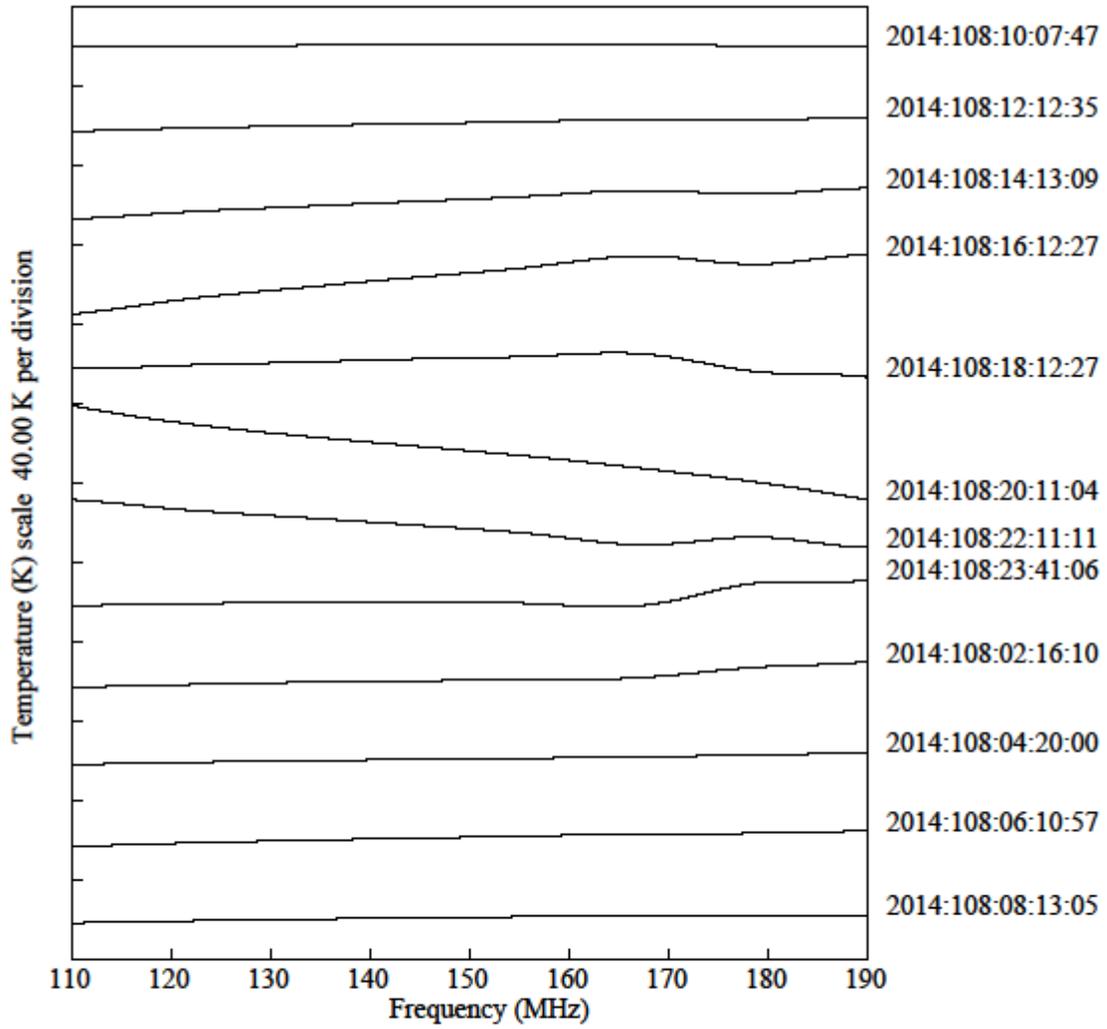


Figure 4. Corrections to spectra. These are large around transit and are plotted on a scale of 40 K per division

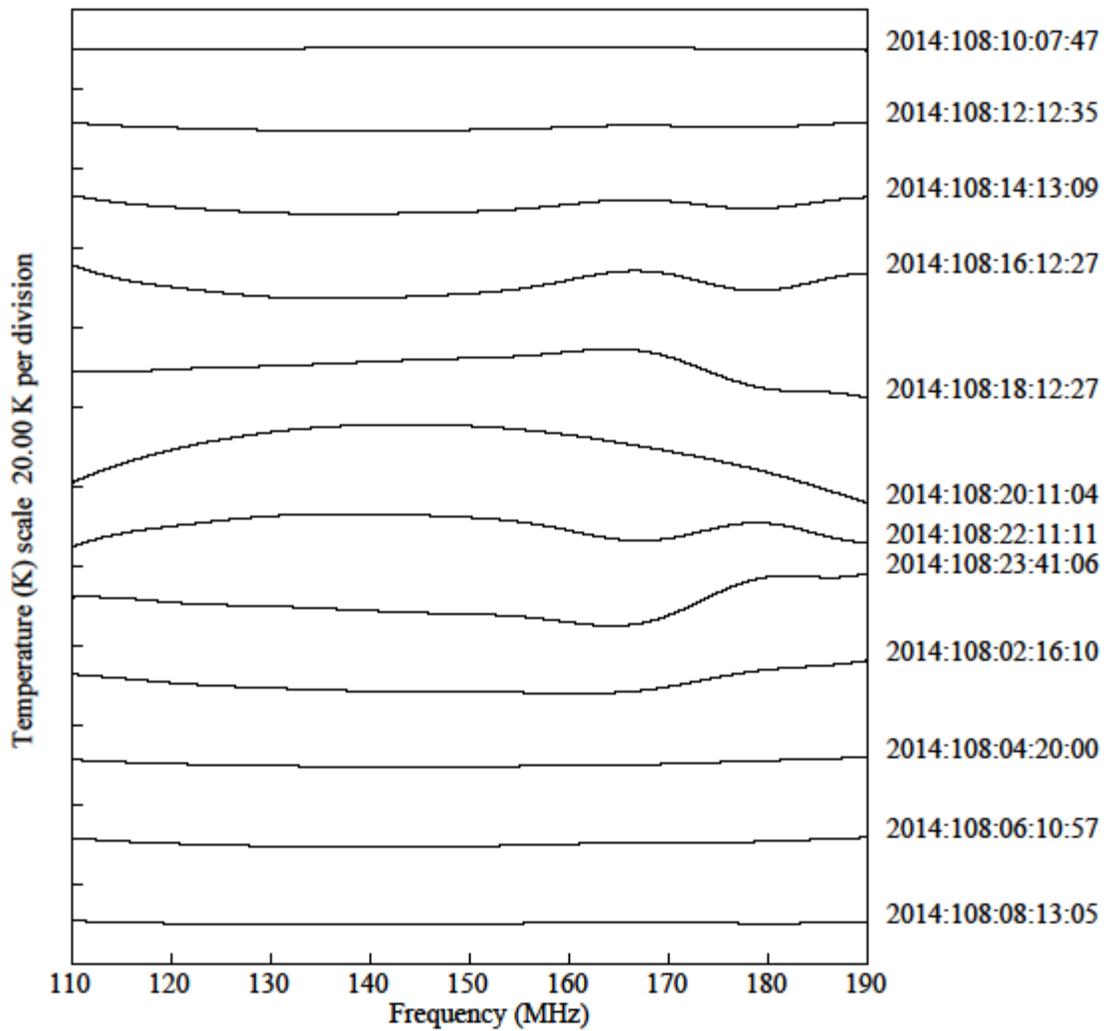


Figure 5. Corrections to spectra after removal of a change in spectral index.

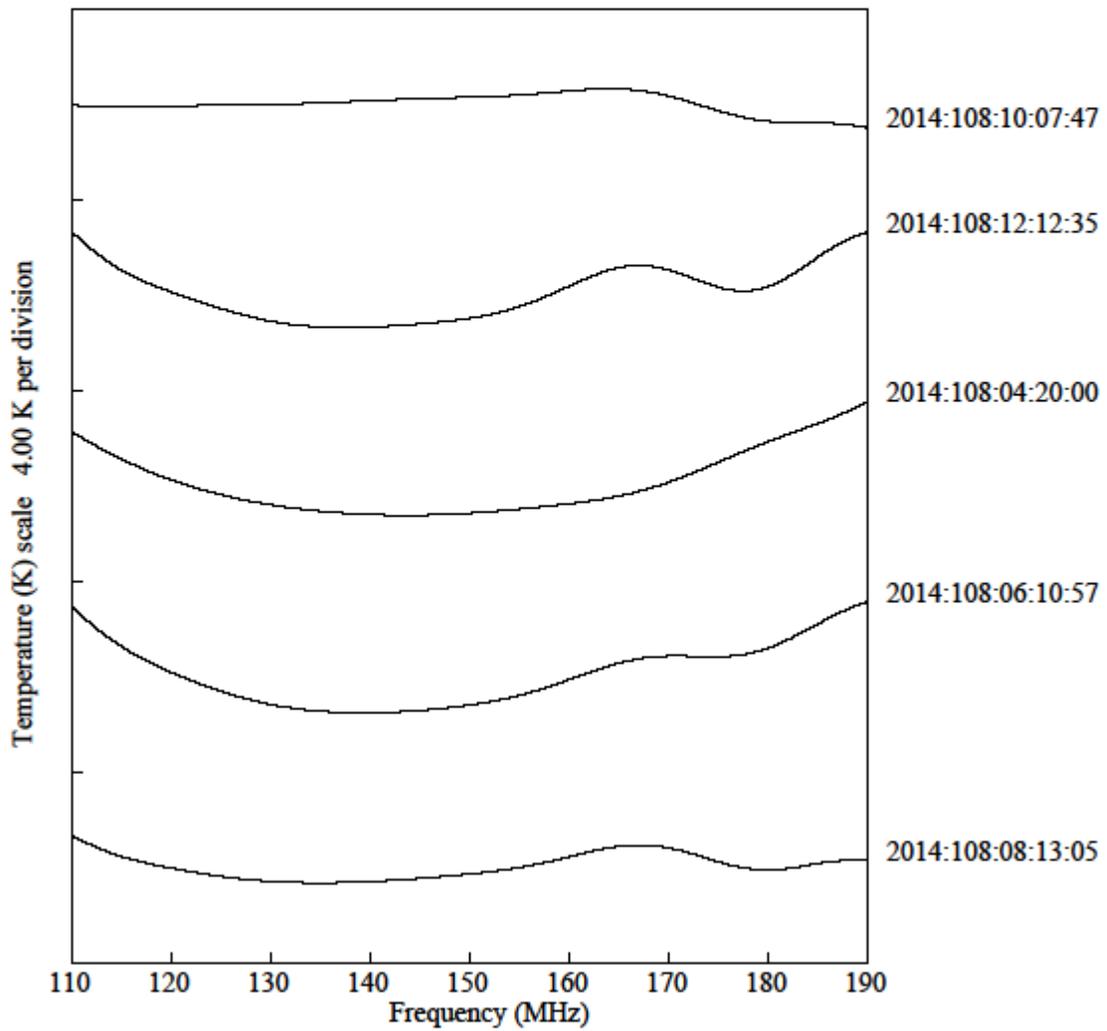


Figure 6. Corrections to spectra after removal of a change in spectra index for Galactic hour angle -10, -8, 8, 10 and 12 hours.