EDGES MEMO #160

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To: EDGES Group

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Subject: Preliminary results for January 2015 deployment

A] Repeatability

The EDGES-2 high band deployment in late 2014 was upgraded in January 2015 following a failure of thermal control in 2014. In January 2015 antenna was upgraded with lower tip capacitance to avoid a resonance around 190 MHz present in the 2014 deployment. In addition another resonance, not seen in 2014, was traced to a loose contact between the balun tube and the ground plane. Following the repair of the contact the S11 was measured by the automated remotely calibrated VNA on 23 January and the system ran without a problem until 27 January when heavy rain started to degrade the performance of the thermal control and ultimately the receiver failed, possibly due to lightening. The S11 measurement system was used to re-measure the S11 on 26 February with results that were different by about 0.1 dB and 1˚ of phase. In order to independently test the stability of the antenna S11 Figure 1 shows the differences between calibrated spectra taken on January 24 with the data taken on January 26. The differences are much smaller than those which would result from the change in S11. This is illustrated by using the values of S11measured 26 February for the date of January 26 shown in Figure 2. The S11 difference is shown in Figure 3 and might be due to a shift in the ground plane structure as a result of the rain. Another possibility is the absorption of moisture into the G10/FR4 dielectric spacers, fiberglass supports or balun. The temperature on January 26 after was about 10˚ C lower than on January 24 setting a limit on the chance of S11 with temperature well below that of the change is shown in Figure 3.

B] Change in calibrated spectra with sidereal time

The calibrated spectra for each hour relative to the transit of Galactic center (GHA) on 24 January is shown in Figure 4 as residuals to single parameter fit to a spectra index of -2.52 while Figure 5 shows the residuals after a correction derived from the convolution of the antenna beam model from FEKO with the 408 MHz sky map of Haslam with the following modifications to convert the sky map to a frequency range of 100 to 190 MHz.

a) Spectral index

$$(mp-3)\left[(1-wb)\left(f/408\right)^{+\beta_0+\gamma_0\ln(f/150)}+wb\left(f/408\right)^{+\beta_1+\gamma_1\ln(f/150)}\right]+3$$

Where $wb=\left(\cos(\ell)+1\right)/2 \qquad b<9°$

= 0 otherwise

ℓ, b are Galactic coordinates

$f =$ frequency

mp = Haslam map at 408 MHz

β_0, γ_0 are spectral index and curvature out of the Galactic region plane

β_1, γ_1 are spectral index and curvature for the region of the Galactic plane

b) Sun at ℓ = 25 b= -29 on 24 Jan 2015

c) Correction for North Polar Spur (NPS)

The combination of these corrections reduced the rms residual from 16 to 5 K. The dominant correction was that of the Sun and is discussed in memo 159. For further analysis only the data for which the Sun was 10 degrees below the horizon was considered and the plot of these residuals to a single parameter fit is shown in Figure 6. In this case the application of corrections reduces the rms from 1.8 K to 0.9 K as shown in Figure 7.

The spectral index correction to the 408 MHz map also include the "gamma" terms to account for the curvature in spectral index. A search for the values that minimize the overall rms for calibrated spectra with the Sun 10 degrees below the horizon has been made for the 24 January 2015, 31 October 2014 and 29 April 2014.

Date	β_0	γ_0	β_1	γ_1	rms (K)[5]	ratio[6]	Note
24 Jan 15	-2.53	+0.01	-2.8	-0.13	0.9	1.9	1
31 Oct 14	-2.51	+0.02	-2.5	-0.15	1.2	1.5	2
31 Oct 14	-2.51	+0.02	-2.7	-0.10	1.5	2.7	3
29 Apr 14	-2.42	-0.02	-2.7	-0.10	3.6	3.3	4

Table of spectral index (β) and curvature (γ) from calibrated EDGES-2 data.

Notes: 1] GHA -11, -10, -9,-8, -7, -6, -5, 10, 11, 12

2] GHA 10, 11, 12 (i.e. those in common with 24 Jan)

3] GHA -11, 4, 5, 6, 7, 8, 9, 10, 11, 12

4] GHA -9 to +2

5] rms after correction

6] ratio of rms before correction to that after correction

A) General comments on the results:

These results are very preliminary and come from limited data. The data from 29 April 2014 is corrupted by the very large frequency dependence of the beam due to the receiver box, which at that time had to be placed under the antenna.

Comparison with other data

The following table compares the spectral index and curvature from those estimated by eye from Figure 10 of Oliveria-Costa et al (2008).

	β_0	γ_0	β_1	γ_1
EDGES	-2.5±0.3	0±0.03	-2.7±0.1	-0.13±0.05
Oliveira-Costa	-2.6	-0.1	-2.4	-0.2

Table 2 comparison with Figure 10 of Oliveira-Costa et al.

While the EDGES errors are difficult to estimate there are 2 differences which stand out. First the spectral index in the Galactic plane appears to be more negative than the out of the plane at 150 MHz which is not in agreement the estimates determined from sky maps made a range of frequencies. One possible explanation is that the estimate from EDGES includes only data taken at night which the ionosphere has minimum effect on "flattening" the spectral index. Second the curvature (γ) of the region out of the plane measured by EDGES is very small and significantly less than that obtained from sky maps. This could also be the result of the ionosphere not being well enough removed from the sky maps.

Further examination of the "feature at 115 MHz" which was reported in memo 158. It is now thought that this is not a relatively narrow feature at 115 MHZ but a curvature of the spectrum at the low end of the 100-190 MHz band which becomes sharpened to peak at 115 MHz when a looking at the residuals to a polynomial fit of several terms. For this reason the analysis in this memo is limited to the removal of a single function of constant spectral index. Figure 6 shows the feature at -5 hours GHA. This feature gets more pronounced at -4 hours GHA but this could be the result of the Sun, which is rising, or the ionosphere which is increasing. Another possibility is the effect of the spectrum of the North Polar Spur (NPS) which is thought to be the remnant of a nearby supernova whose spectrum turns over at low frequencies. The rms can be reduced to 0.8 K by giving the region centered at $\ell = 27°$, b=45˚, of 30˚ extent a spectrum with $\alpha = -3, \gamma = -0.5$ to simulate the NPS. However nighttime data in the GHA range -5 to 0 hours GHA is needed to further test this hypothesis.

De Oliveira-Costa, Angélica, Max Tegmark, B.M. Gaensler, Justin Jonas, T.L. Landecker, and Patricia Reich. "A model of diffuse Galactic radio emission from 10 MHz to 100 GHz." Monthly Notices of the Royal Astronomical Society 388, no. 1 (2008): 247-260.

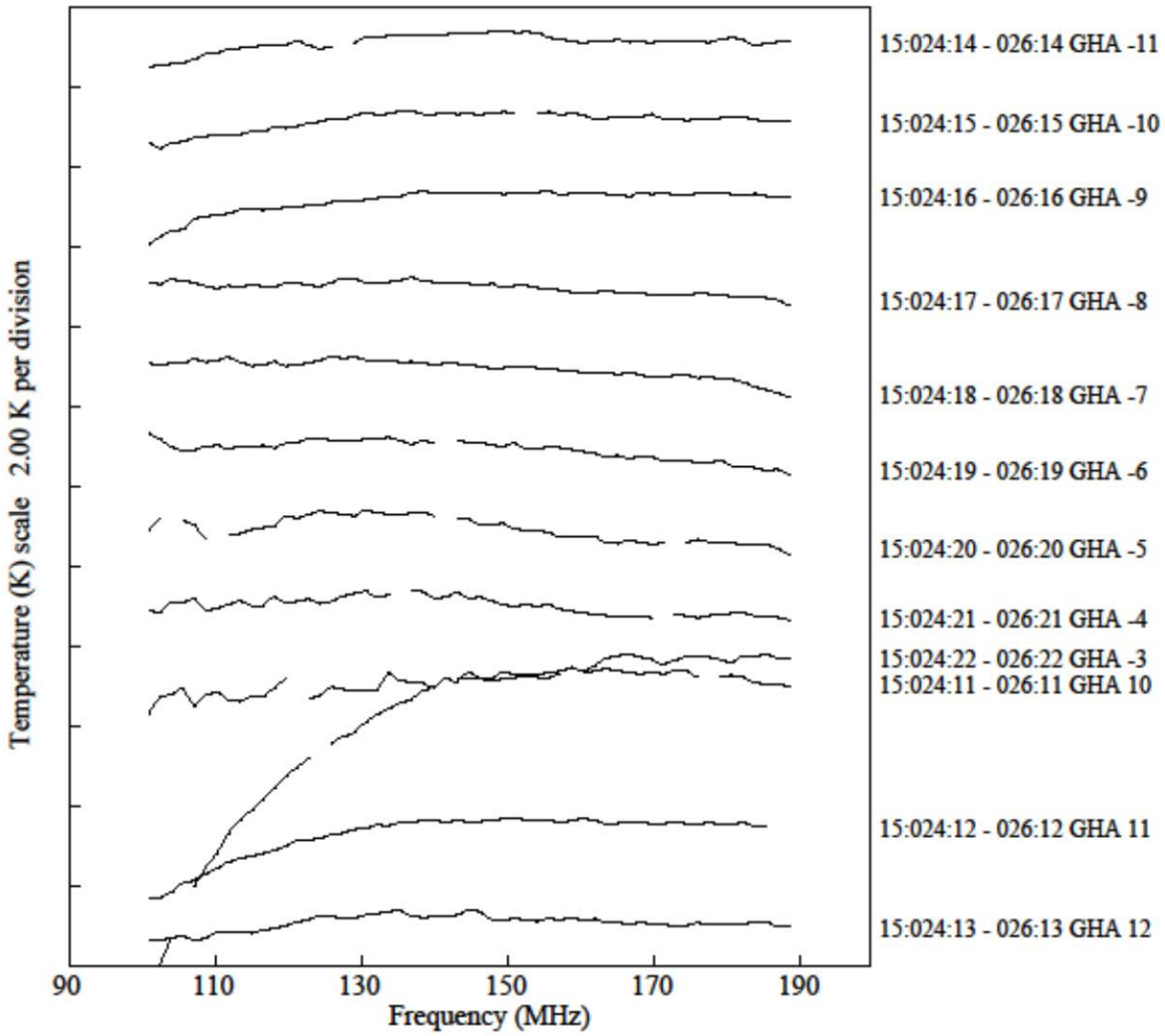

Figure 1. Difference between calibrated spectra on 24 January 2015 and 26 January 2015.

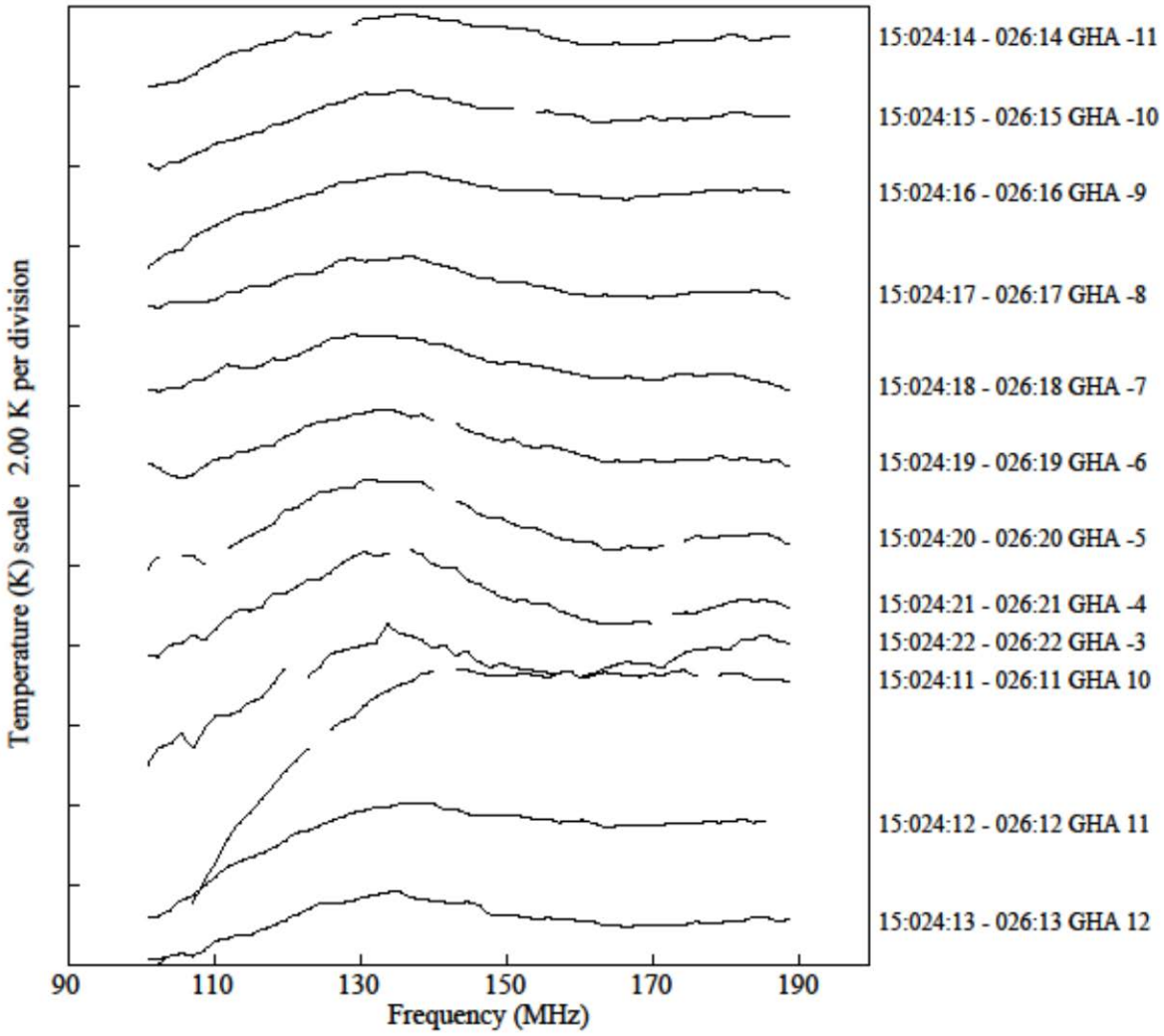

Figure 2. Difference using S11 from 26 February 2015 to calibrate 26 January 2015 data.

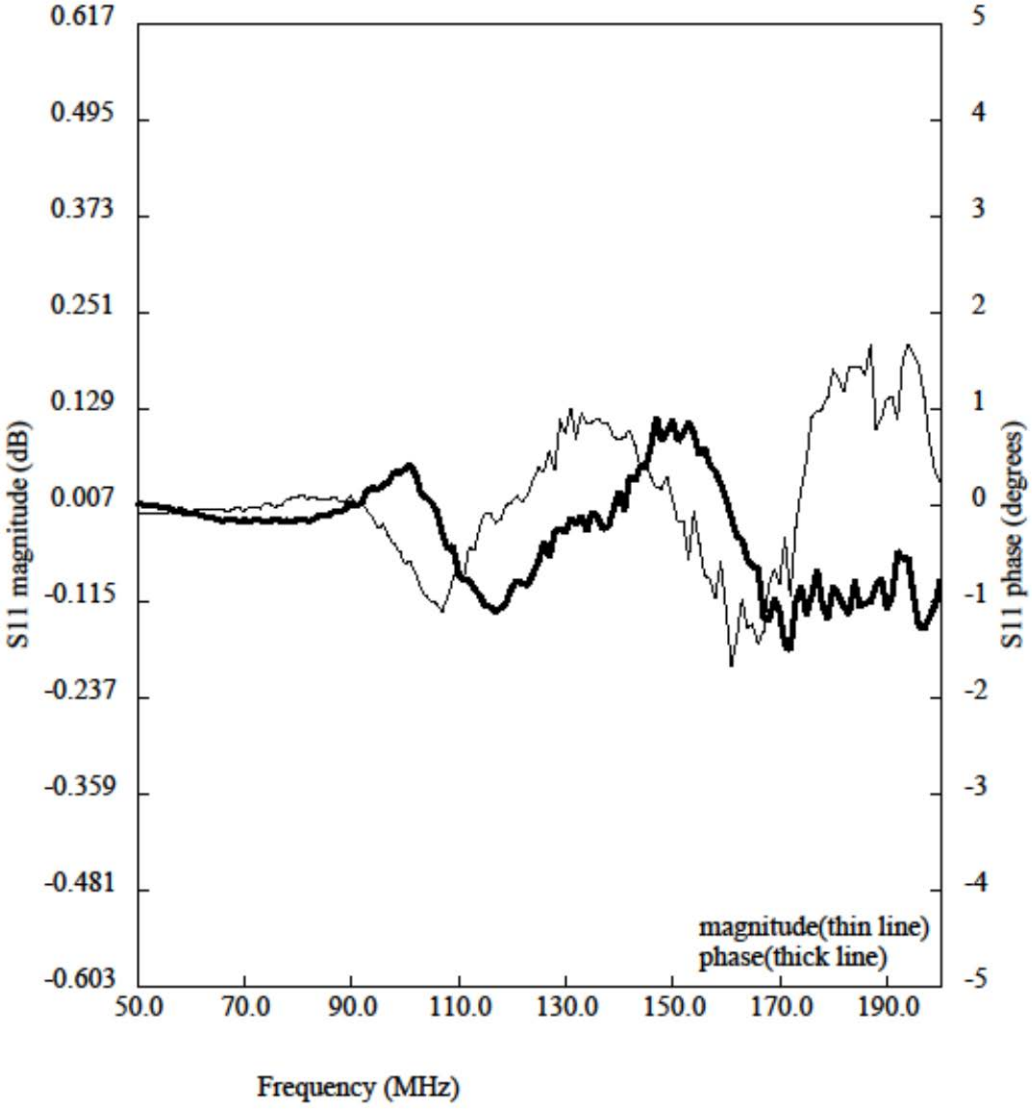

Figure 3. Difference using S11 taken 23 January and 26 February 2015.

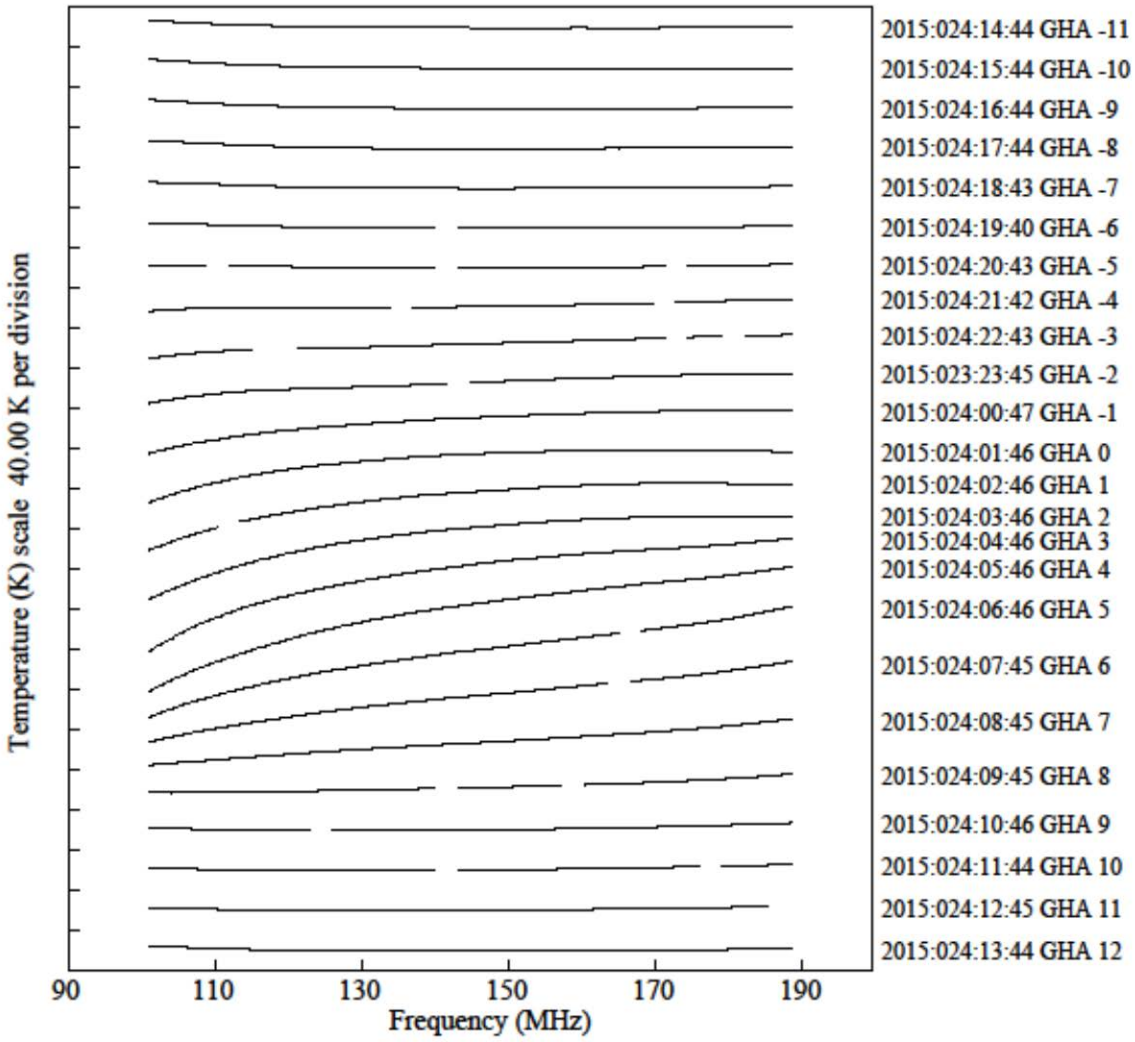

Figure 4. Residuals of calibrated spectra to a single fit to spectral index -2.52

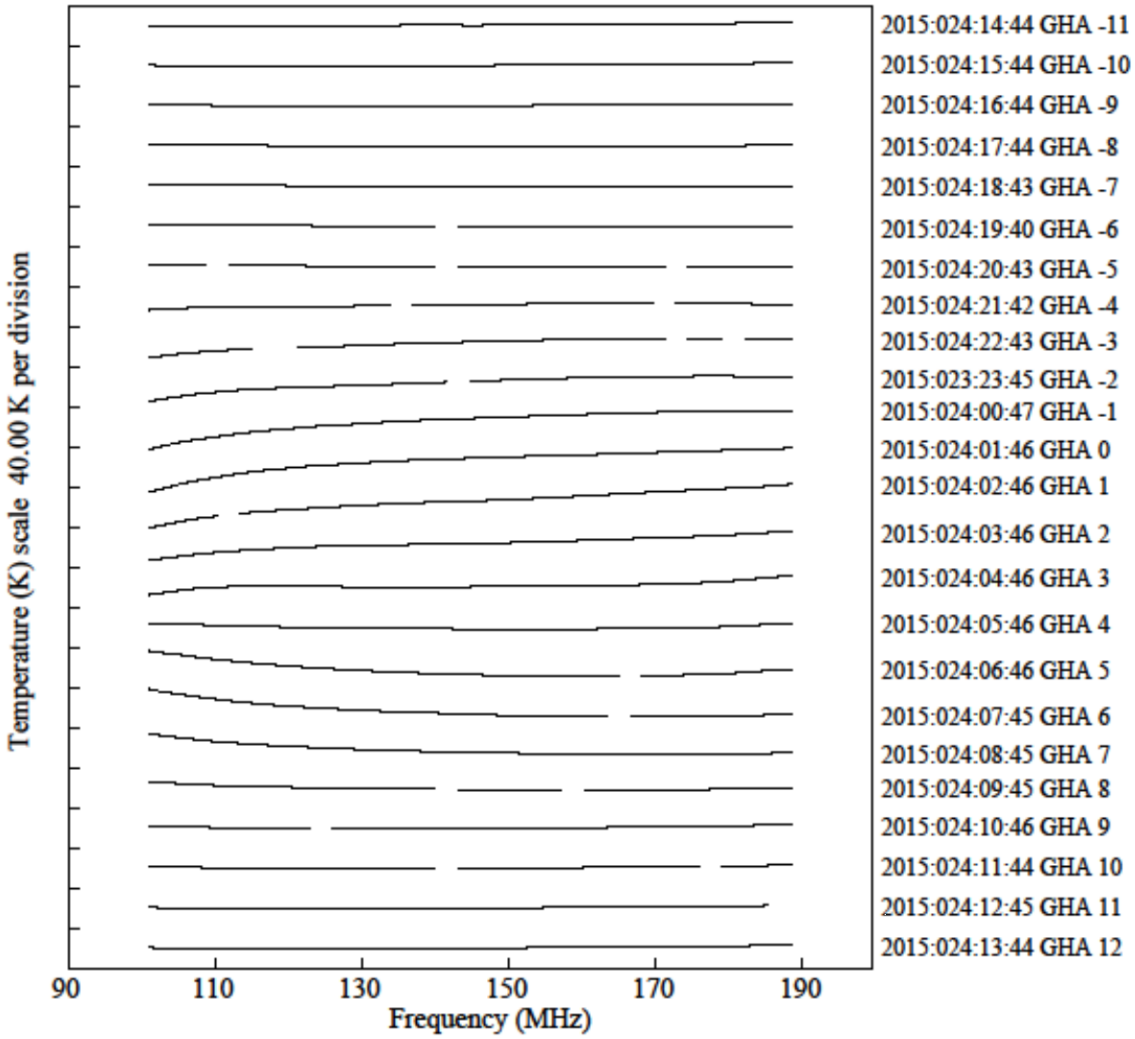

Figure 5. Residuals following corrections – see text.

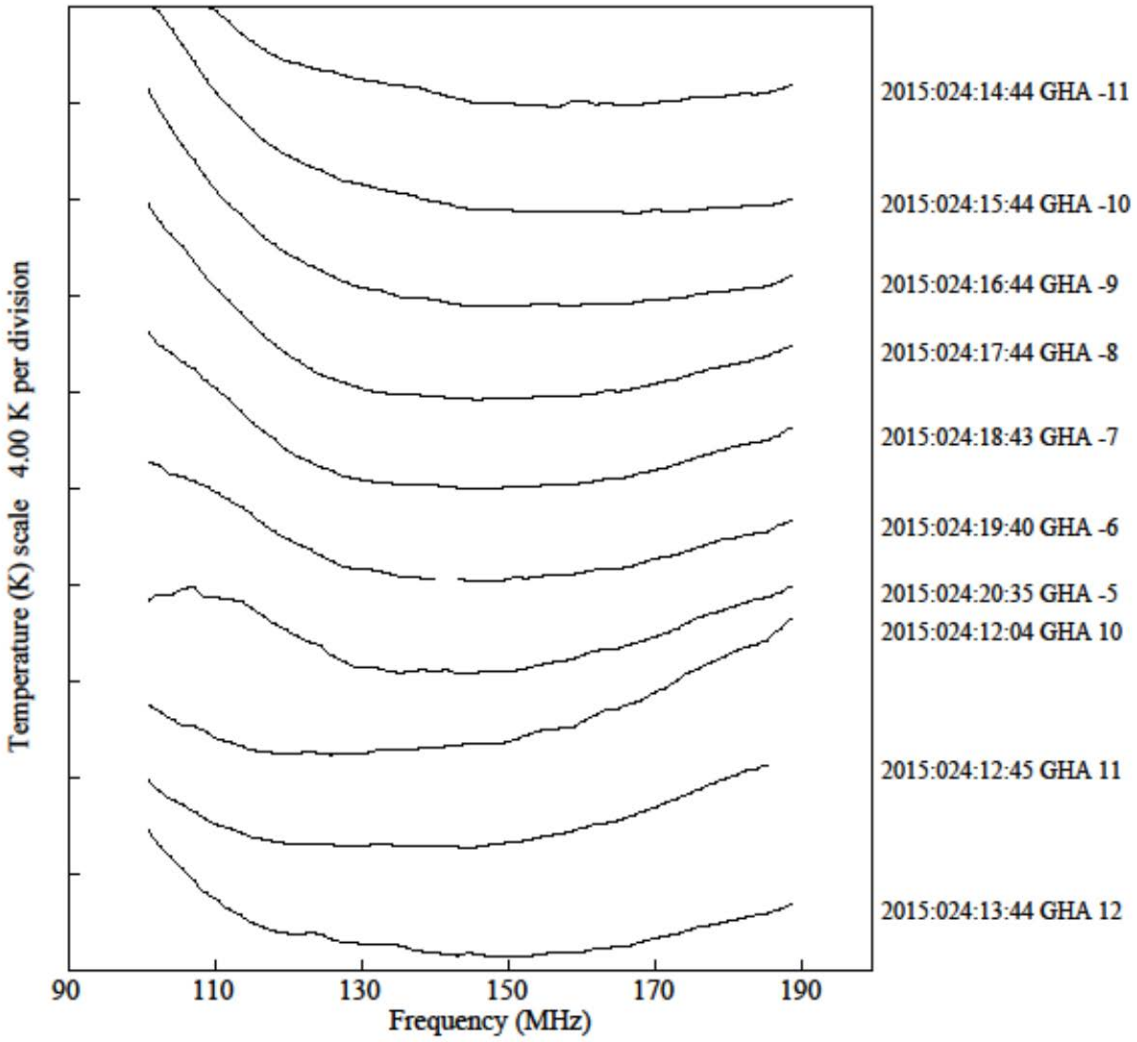

Figure 6. Residuals to spectral index of -2.52 without correction for GHA when Sun was below - 10 degrees elevation.

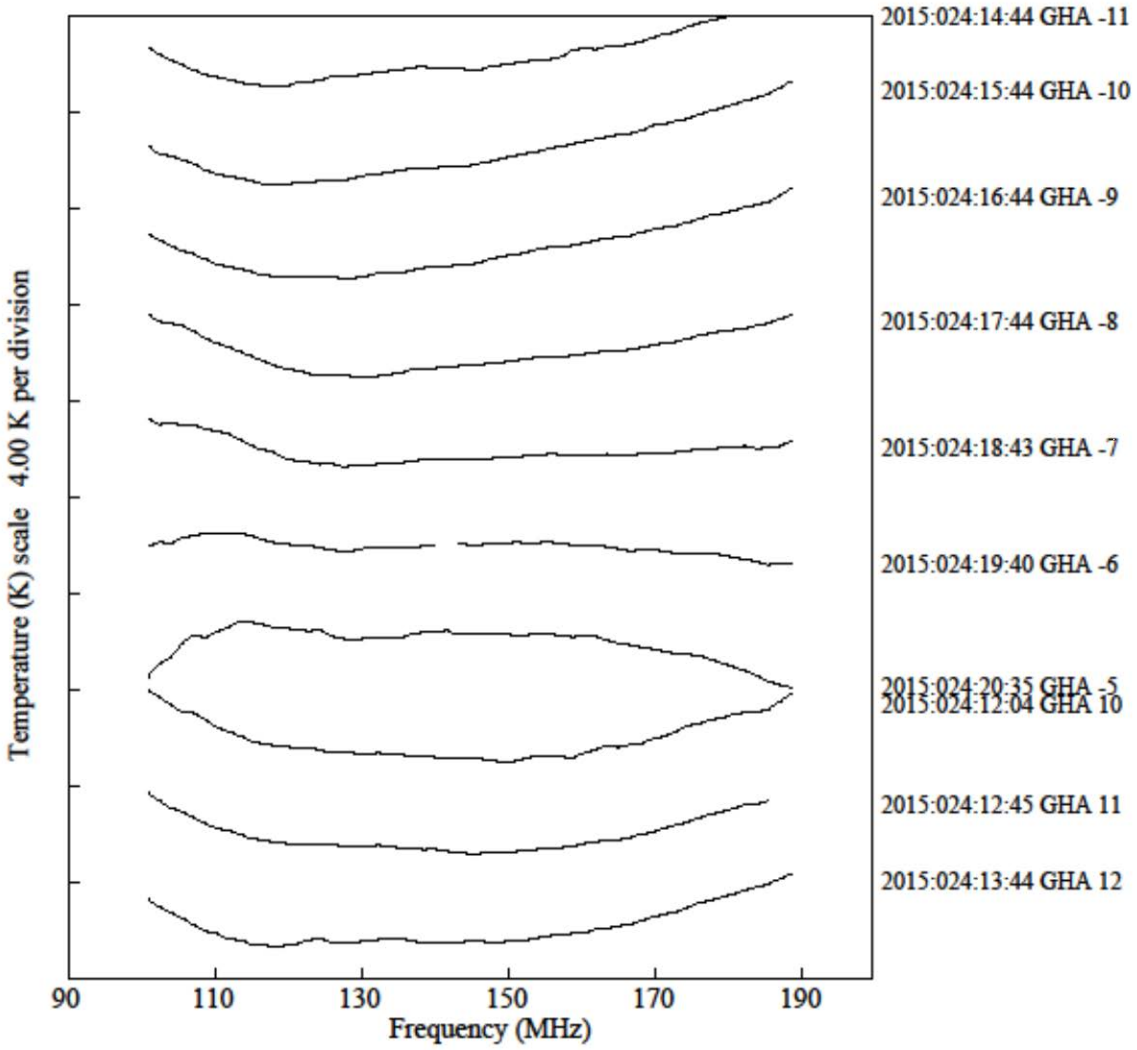

Figure 7. Residuals following corrections (see text).