To: EDGES Group  
From: Alan E.E. Rogers  
Subject: Characteristics and stability of EDGES electronics

The EDGES-2 spectrometer uses 3-position switching to remove most of the changes in the spectra due to component aging and temperature changes. However the 3-position switching does not remove the following:

1. Changes in the LNA input S11 and noise waves with time and temperature.
2. Changes in the comparison load S11 with temperature and changes in comparison load temperature.
3. Changes in the noise diode output and spectral flatness.

To reduce these changes the entire “front-end” box, which contains the 3-position switch, LNA and post amplification, is temperature controlled to within about 0.2 K. While different parts of the electronics will take on different temperatures due to the internal heating these temperatures should remain stable and repeatable provided the box orientation remains constant and the heat loss away from the thermoelectric element also remains fairly constant. To minimize the effect of temperature change on the noise diode a thermistor increases the current with increasing temperature to reduce the temperature coefficient of its output from about 0.3\%/°C to about 0.05\%/°C. For 1000 K signal this corresponds to a decrease of 500 mK/K because the increase in noise diode output decreases the 3-position switched output.

The LNA is designed (see memos 62 and 102) to have a good match. Typical LNA S11 is below -22 dB at 50 MHz and below -18 dB at 200 MHz. The S11 temperature coefficient and delay coefficient are about 0.02dB/°C and −0.004ns/°C respectively.
EDGES-2 “Front-end” electronics characteristics:

LNA Frequency Range 50 to 200 MHz

- LNA uncorrelated noise wave 90 K
- LNA and 2\textsuperscript{nd} stage additive noise 50 K
- LNA correlated noise wave 15 K
- LNA input S11 -20 dB
- Gain 40-200 MHz 21 dB
- Gain below 30 MHz <7 dB

Fraction of signal power over “out of band” added noise when input is connected to load 2%

- DC control voltages 16, 20, 24 v
- DC current 320, 510 ma

Maximum input level for <0.02 dB effect on LNA S11 -25 dBm

- Temperature coefficient of LNA |S11| 0.02 dB/°C
- Temperature coefficient of LNA S11 delay -0.004 ns/°C

- Noise diode level (via 30 dB attenuator) 400 K
- Temperature coefficient of noise diode 0.05%/°C

- “Out of band” noise 5-40 MHz

- Temperature monitor tone 1.8309 MHz at 25°C

1 dB compression point referred to input for out of band signal -25 dBm

Estimate of out of band signal for less than 1 mK effect on in band -55 dBm
EDGES-2 “Back-end” electronic characteristics

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>2-200 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain 50-190 MHz</td>
<td>43 dB</td>
</tr>
<tr>
<td>Gain 195 MHz</td>
<td>36 dB</td>
</tr>
<tr>
<td>Gain 205 MHz</td>
<td>5 dB</td>
</tr>
<tr>
<td>Maximum cable length (LMR-400)</td>
<td>500 ft.</td>
</tr>
<tr>
<td>Maximum cable length (LMR-240)</td>
<td>240 ft.</td>
</tr>
<tr>
<td>1 dB compression point</td>
<td>15 dBm</td>
</tr>
<tr>
<td>A.C. power</td>
<td>110/220 (20 W)</td>
</tr>
</tbody>
</table>

Notes

1. For 50-100 MHz a higher level of comparison noise is desirable. The level can be increased by reducing the attenuation.
2. Bias tees are modified to remove ferrite, remove the current dependence of loss see memo 67.

The overall circuit/block diagram of the front and back ends are shown in Fig 1. The circuit diagram of the LNA, out of band noise, temperature monitor are shown in Figures 2, 3 and 4. The thermal control and installation diagram are shown in Figures 5 and 6.

Photos of the electronics are shown in Figures 7 and 8.
Figure 1. Block diagram with control electronics

Figure 2. 3-position switch, LNA and comparison noise
Figure 3. “out of band” noise source

Figure 4. Temperature monitor
Figure 5. EDGES-2 Thermal control for LNA

- Calibration constants are measured in the lab using ambient and hot load as well as open/shorted cable along with both of ambient, hot load, open/shorted cable and LNA.
- Antenna H1 is measured in field.
- Cable to shelter approx. 300 feet (LNB-400).
- An optional attenuator can be inserted between the antenna cable and the LNA.

Figure 6. EDGES-2 Installation diagram

- Proposed EDGES2 installation
- Temperature controller
- Splitter Curtis F1300AA15
- Temperature-controlled box for LNA exchange of outside air, possibly on a given to heat exchange with ground through the box wall should suffice.
Figure 7. EDGES-2 LNA, 3-position switch and comparison noise source.
Figure 8. EDGES-2 LNA and “front-end” electronics box and the “back-end” electronics box.
Figure 9. Updated LNA schematic for receiver in 2017.
Figure 10. Updated receiver schematic for receiver in 2017.