To: EDGES Group  
From: Alan E.E. Rogers  
Subject: Details of EDGES-3 prototype

The concept of placing all the electronics in the antenna was proposed in memo 289. An update to the design, in which the number switches in reduced, is described in memo 293. Simulations of the EDGES-3 beam chromaticity are given in memo 294 and in memo 298 with a wire grid ground plane. Following early tests of the initial EDGES-3 prototype it was discovered that RFI generated by the Nuvo PC, DC to DC converters and other switching electronics was strong enough to require an additional layer of shielding and filtering as described in memo 299.

This memo gives details of the revised design based on separating the electronics with fast switching waveforms into a separate “inner” box. The analog “backend” electronics is also contained in the box to provide additional isolation to prevent feedback of the amplified sky signal into the antenna. A block diagram is given in Figure 1a along with a photo in Figure 1b. The VNA and its DC/DC converter is outside the inter shielded box because the spectrometer is not run when the S111 measurements are made with the VNA.

Figure 2 shows the overall circuit diagram of EDGES-3. The ethernet connections to the outside and to the VNA are made using fiber. A cable connection to the outside can be made for charging the batteries. This connection is made, which the EDGES-3 is not running, via a cable which passes through the pipes which connect the antenna boxes shown in Figure 12.

<table>
<thead>
<tr>
<th>Register</th>
<th>Parameter</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>temperature</td>
<td>Frontend box</td>
</tr>
<tr>
<td>101</td>
<td>temperature</td>
<td>Ambient load</td>
</tr>
<tr>
<td>102</td>
<td>temperature</td>
<td>Hot load</td>
</tr>
<tr>
<td>103</td>
<td>temperature</td>
<td>PR59 in inner box</td>
</tr>
<tr>
<td>106</td>
<td>Output %</td>
<td>Thermal control</td>
</tr>
<tr>
<td>150</td>
<td>Voltage</td>
<td>Battery</td>
</tr>
<tr>
<td>152</td>
<td>Current</td>
<td>PR59 current</td>
</tr>
</tbody>
</table>

Table 1 Some key parameters monitored.

Table 1 lists the key registers which can be read out for monitoring purposes via the RS232 link from the Nuvo PC to the PR59 thermal controller. When S11 measurements are needed the VNA can be powered up using the MEZIO control and after a delay for the VNA to reach a stable temperature the control and data retrieval is performed using the Ethernet link to the VNA.

Figure 3 shows the mechanical details of the frontend. The left box contains a 10 ft long cable with a switch which provides an “open” or a “short”. The middle box contains a 50 ohm load which is heated by a 75 ohm resistor and filled with Aerogel Silica Gel Lumira LA100 for insulation. Figures 4, 5 and 6 show the circuits of the LNA, noise source, and “out of band” noise.
Figure 7 shows the circuit of the “switch board” which converts the MEZIO “pulldown” outputs to “pullup” outputs to control the R.F. switches. Figure 8 shows the circuit details of the inner box and Figure 9 shows the mechanical details.

Figure 10 shows the layout of the outer box and Figure 11 gives the dimensions of the antenna box. Figures 13 give the dimensions of the antenna base.

<table>
<thead>
<tr>
<th>Items</th>
<th>Conditions</th>
<th>Volts</th>
<th>Amps</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontend</td>
<td></td>
<td>12</td>
<td>0.8</td>
<td>10</td>
</tr>
<tr>
<td>Frontend + PC</td>
<td>Idle</td>
<td>13</td>
<td>1.9</td>
<td>25</td>
</tr>
<tr>
<td>Frontend + PC</td>
<td>Fastspec running</td>
<td>13</td>
<td>5.5</td>
<td>72</td>
</tr>
<tr>
<td>Thermal</td>
<td>Max</td>
<td>13</td>
<td>2.0</td>
<td>26</td>
</tr>
<tr>
<td>VNA</td>
<td>Only</td>
<td></td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>VNA + PC + thermal</td>
<td>Min</td>
<td></td>
<td></td>
<td>39</td>
</tr>
<tr>
<td>All</td>
<td>Min in spectra</td>
<td></td>
<td></td>
<td>72</td>
</tr>
<tr>
<td>All</td>
<td>Max in spectra</td>
<td></td>
<td></td>
<td>98</td>
</tr>
</tbody>
</table>

Table 2. Power consumption for different items and conditions.

Table 2 gives the level of power consumption for parts of the system and different modes of operation. Theoretical models show that 98 watts, should only result in a 5 deg C temperature rise, via combination of the radiation and convection. A test was made in which a 75 W lamp and a 20 W fan were placed in an antenna box resulted in a 10 deg C temperature rise. This test was made before applying goldstone paint that increases the IR emittance. A test of placing the antenna box in the Sun resulted in a rapid rise of the 10 deg C. More tests are underway to ensure that thermal control, at least under conditions at night in Oregon. Operation during day may require circulating air through the antenna box via plastic pipe to heat exchange box in the under the antenna or a control hut as in EDGES-2. For initial operations in Oregon the wires for charging the batteries shown in the circuit of Figure 2 will only be connected via the lower box in Figure 12 during periods when the spectrometer or VNA are not running so any RFI from the charging source or cable is avoided.
Figure 1a. Block diagram of EDGES-3.
Figure 1b. Electronics with inner box cover removed.
Figure 2. Overall circuit diagram
Figure 3. Frontend box layout.
2.2 uH 587-2899-1-ND 0603
27 ohm A1013186CT-ND 0805
1.0 K P1.0K DECT-ND 0402
75 nH 445-6317-1-ND 0402
270 nH PCD-1054CT-ND 1008
470 nH PCD-1057CT-ND 1008
Minicircuits SAV-541+ in an alternate for ATF-54143

Figure 4. LNA Circuit
Figure 5. Noise source

NTC 100 ohms
at 25°C RL2003-62.4-73-k
GE Sensing Type RL20 beta = 3468
Figure 6. Out of band noise source.
Figure 7. Switch board circuit

A = normally a short but could be open
B = short or a 2.2 uH inductor 587–2899
C = open or 0.01 uF
D = normally diode 641–1002–1–ND or open
Figure 8. Circuit of electronics in inner box
Figure 9. Inner box layout
Figure 10. Outer box layout
Figure 11. Outer box dimensions.
Figure 12. Connections between antenna boxes.
Figure 13. Antenna base.
Antenna Box
1/2\textsuperscript{-}13
93025A297 2\textquoteright long
92174A435 1/2\textsuperscript{-}13 nuts
brass rod with hole into which coax center conductor is soldered
0.5\textquoteright diam 1/2\textsuperscript{-}13 threaded end allows some adjustment of box separation

Connection of receiver to antenna

aeer 3jul19
8T sw 125 ma
LNA 120 without when not charging
Hot 160 external 15 amp charger used
backend 195 with 4 batteries in parallel
CCR 140

2499-003-X5W0-1032LF or
Tusonix 4251-004LF EMI filter feed-thru
75dB at 100 MHz

10VR1
60 dB
at 30MHz

+ +12v to electronics
- 10w
to 12v
K2B12-v10EB
several 10amph batteries
in parallel for 120wh
+ to VNA
DC/DC converter
2-15w
+ to Nuvo PC
30-70w needs > 8v
+ to thermal
controller
10-60w
optional charger
power from
external source
needs to be > 14v
Ferrite cores
on cables

Notes: Nuvo 25w idle 72w running fastspec
electronics + switches + hot 5w
Thermal 10 - 60w
Battery voltage ~ 13v charged

EDGES-3
power system
aer 14aug19
Figure 15. Power system connections.
Figure 16.

Connections using connectors

aeer 14aug19
Figure 17. Connections using connectors

Figure 18.

DIAGRAM OF EDGES-3 FIBER and CABLE PATH
Figure 19. Battery charging.

4 K2B12V10EB Lithium Iron Batteries

- Batteries ran for 39 amperes
- Went down from 13.16 to 12.60V slowly
- pr59 controller LED went red at 10V - seen thru fan vent
- Batteries' internal PCM opening so batt voltage going to zero
- Started 10amp re-charge voltage went
- 12.60 to 13.6V in one hour
- and charge completed in 4 hours

EDGES-3 batteries + charge connection 12aug19
1. Assemble base with washers and nuts under the plywood and horizontal fiberglass sections tightened.
2. Add antenna and receiver box without top covers.
3. Feed fiber from inner box down through hole and unattached pipes.
4. Adjust antenna and receiver box separation so that pipe assembly can be attached with screws from below.
5. Add washers and nuts and tighten.
6. Check that box separation is about 1.5”.
7. Carefully add SMA connection between antenna and receiver box.
8. Connect Laptop via fibers using ST connectors.
9. Put cover on antenna box and connect battery for “no cover test.”
10. Put cover on receiver box – watch temp should be OK to run 30m.
11. Remove receiver box cover – to change battery.

Figure 20. Assembly instructions.