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To: EDGES Group

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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 $0.3\%/^{\circ}C$ to about $0.05\%/^{\circ}C$. 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 $0.02dB/^{\circ}C$ and $-0.004ns/^{\circ}C$ respectively.

EDGES-2 “Front-end” electronics characteristics:

LNA Frequency Range	50 to 200 MHz
LNA uncorrelated noise wave	90 K
LNA and 2 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

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

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.

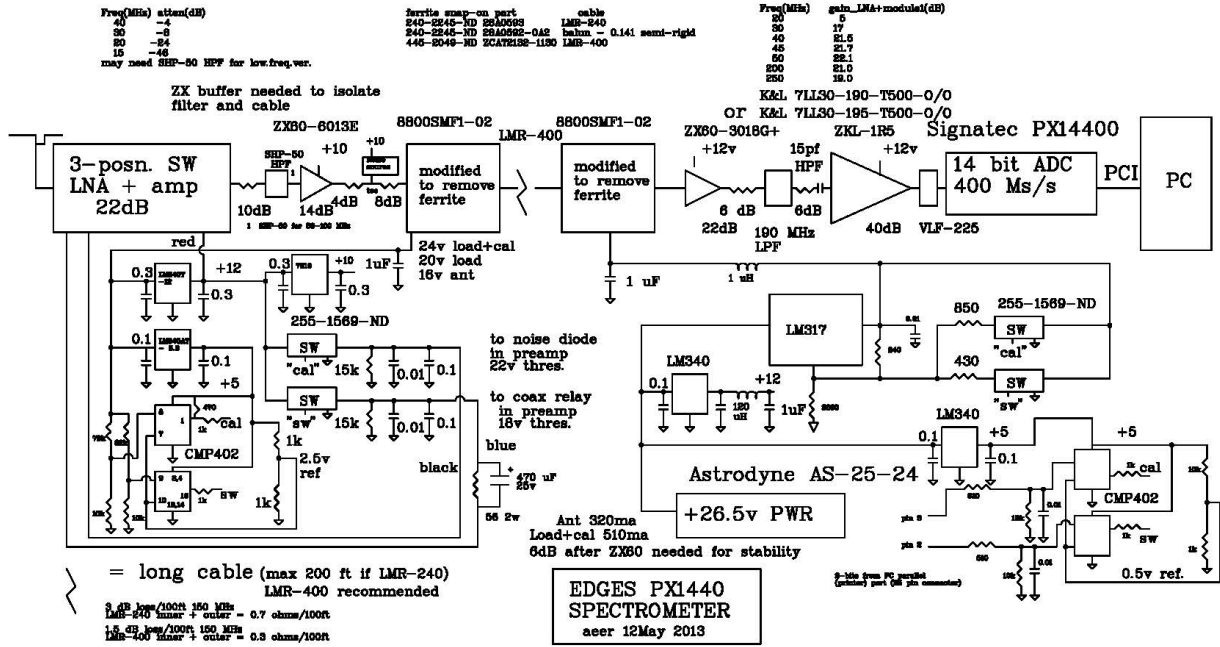


Figure 1. Block diagram with control electronics

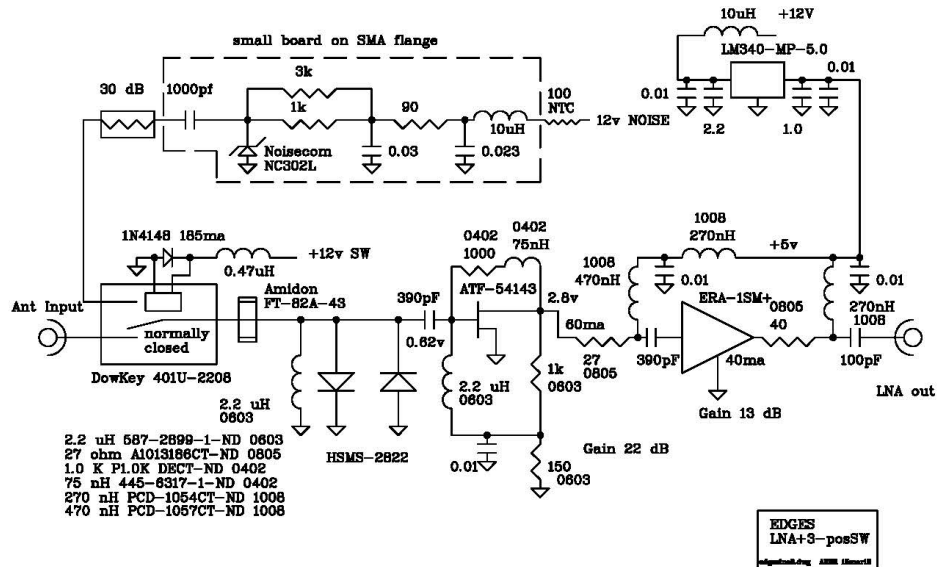


Figure 2. 3-position switch, LNA and comparison noise

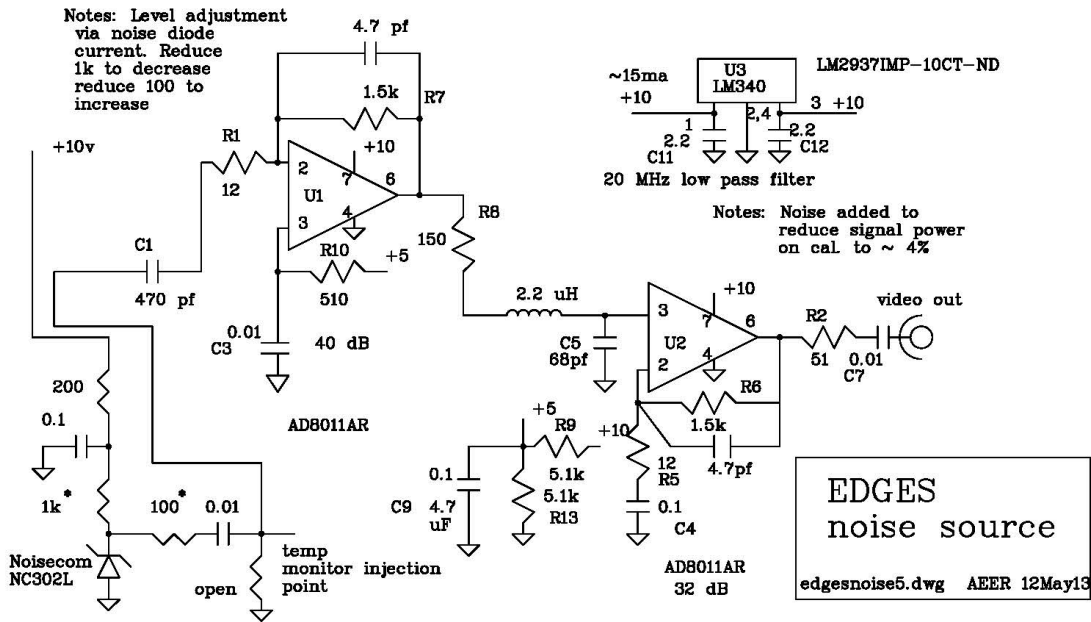


Figure 3. "out of band" noise source

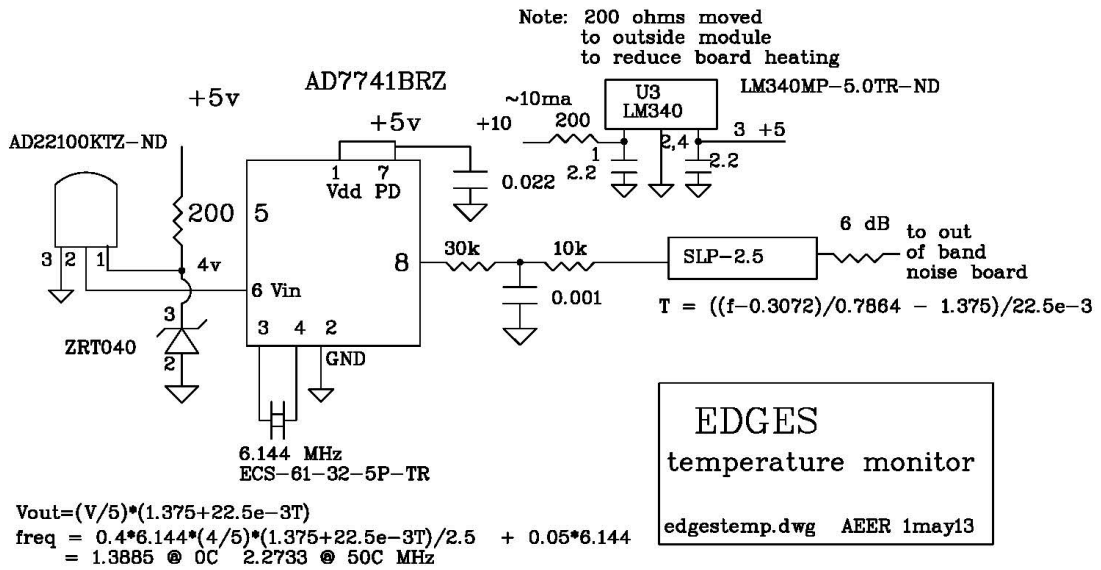


Figure 4. Temperature monitor

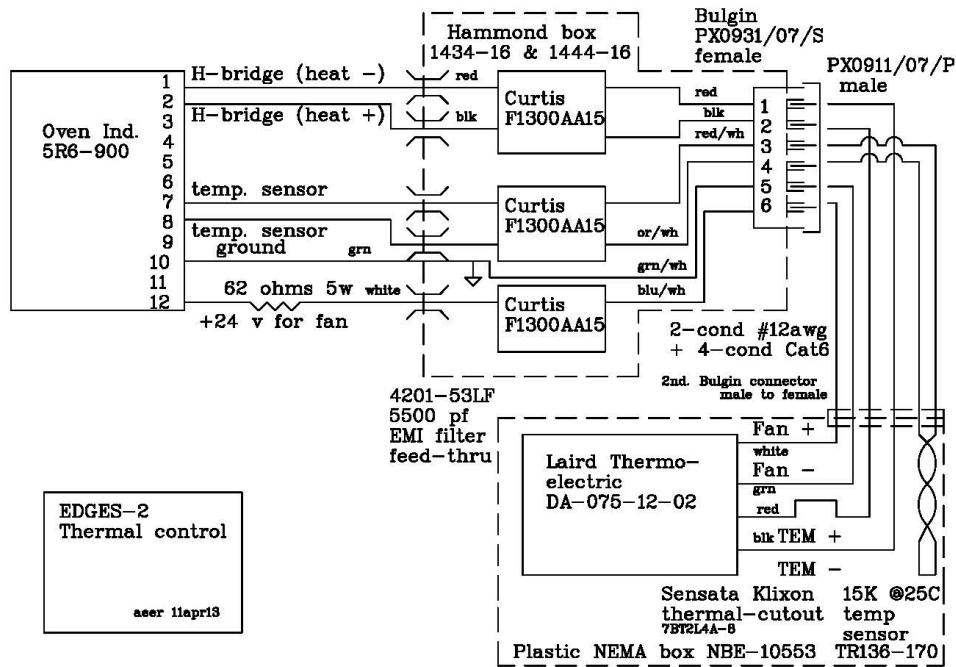


Figure 5. EDGES-2 Thermal control for LNA

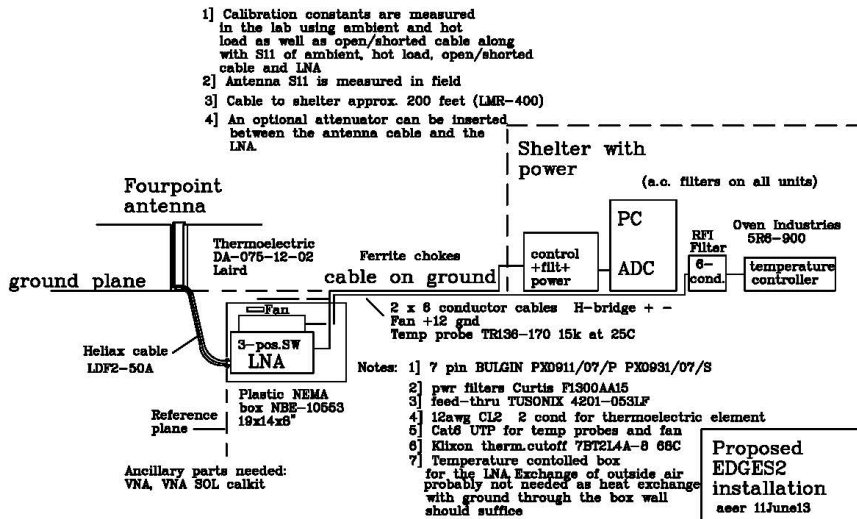


Figure 6. EDGES-2 Installation diagram

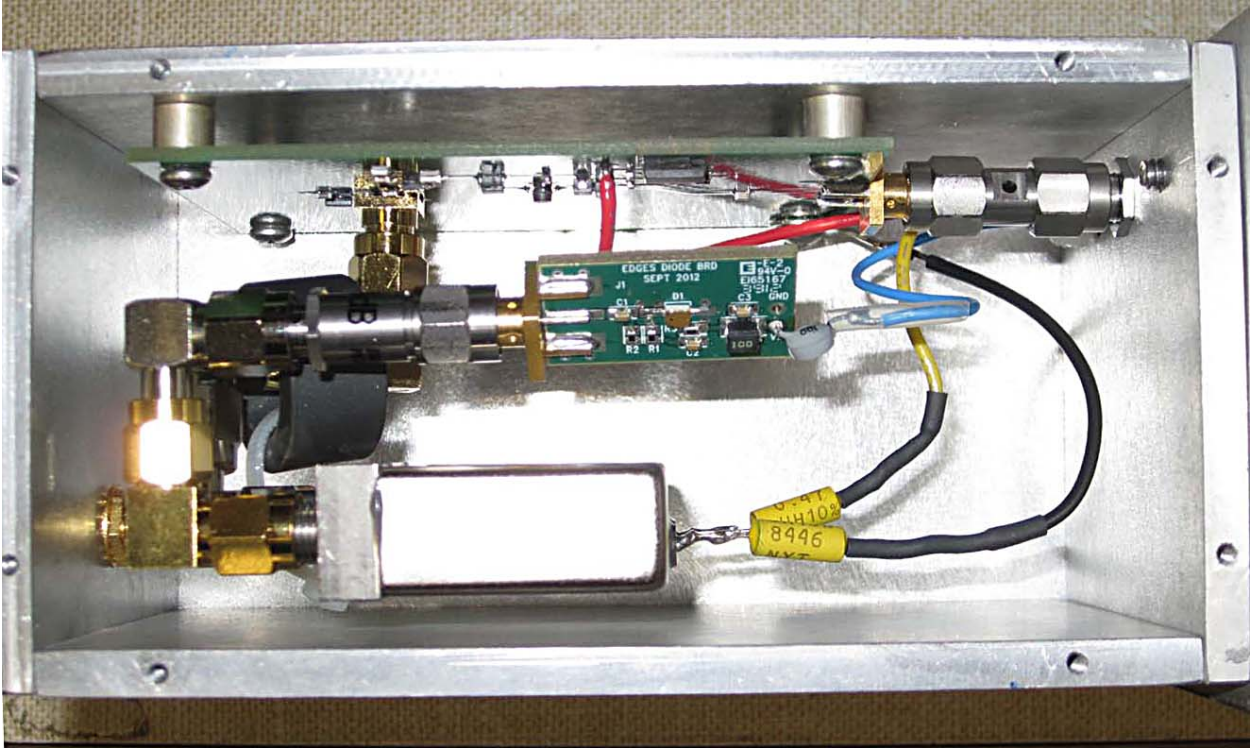


Figure 7. EDGES-2 LNA, 3-position switch and comparison noise source.

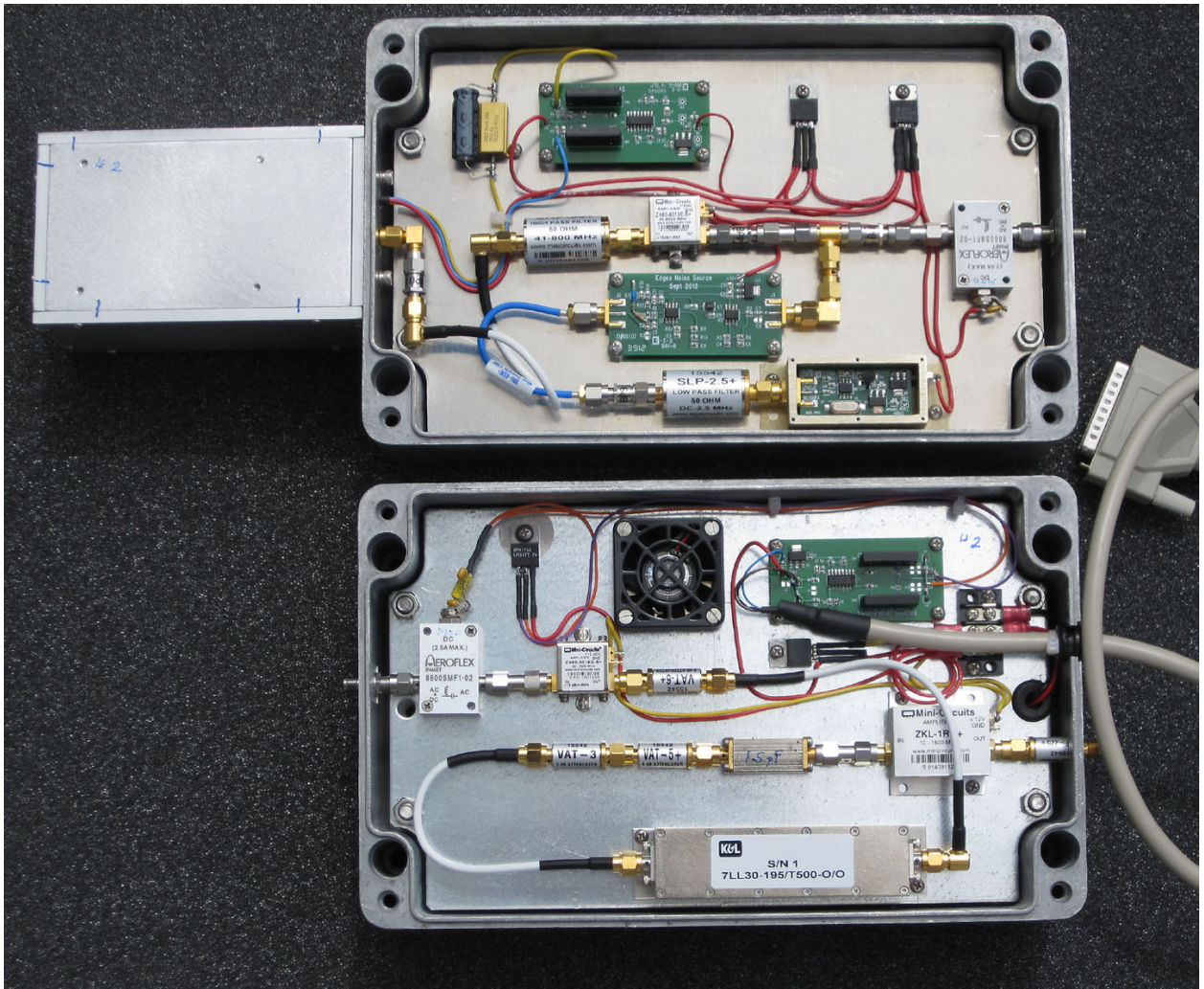


Figure 8. EDGES-2 LNA and “front-end” electronics box and the “back-end” electronics box.

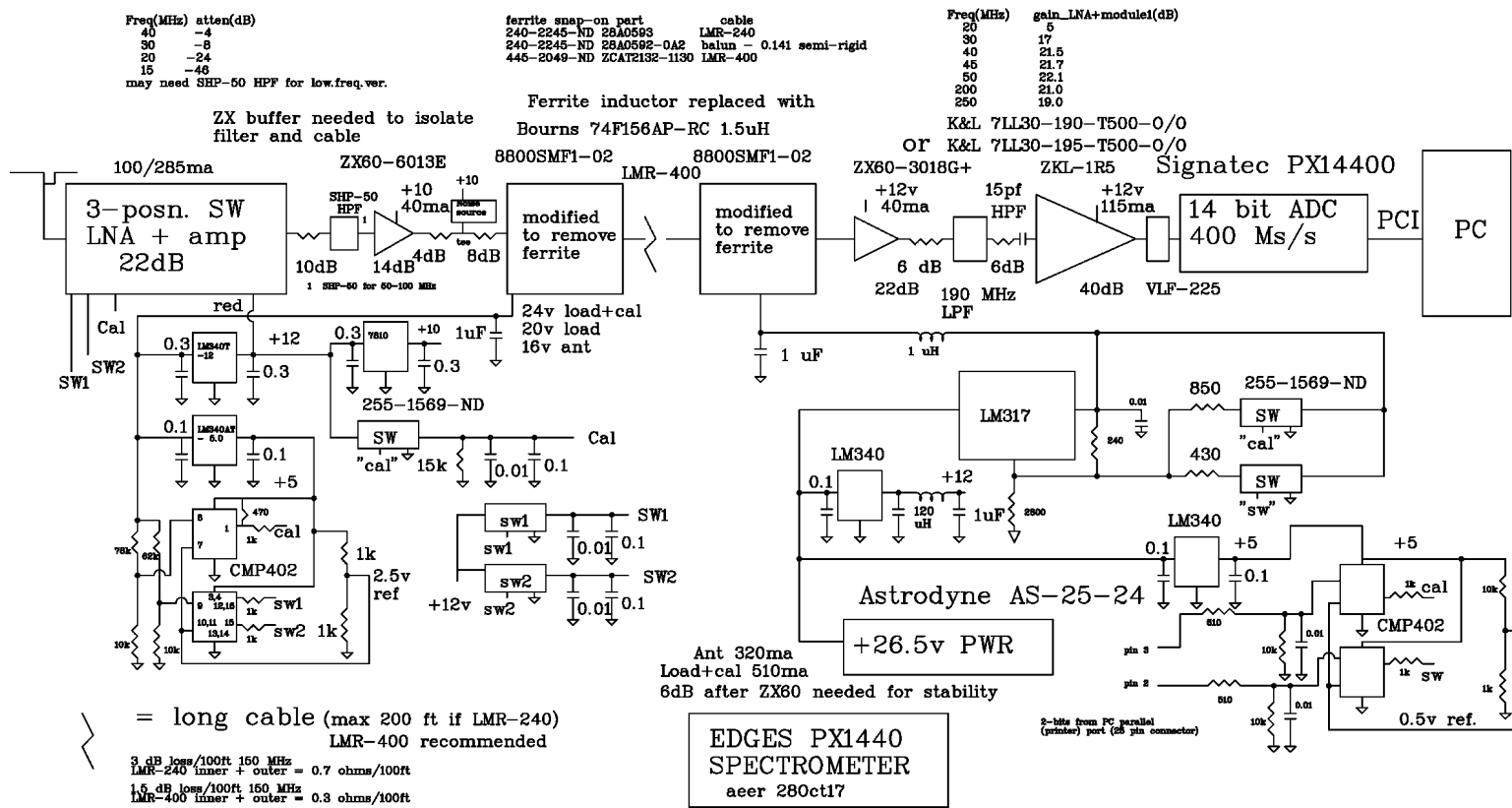


Figure 9. Updated LNA schematic for receiver in 2017.

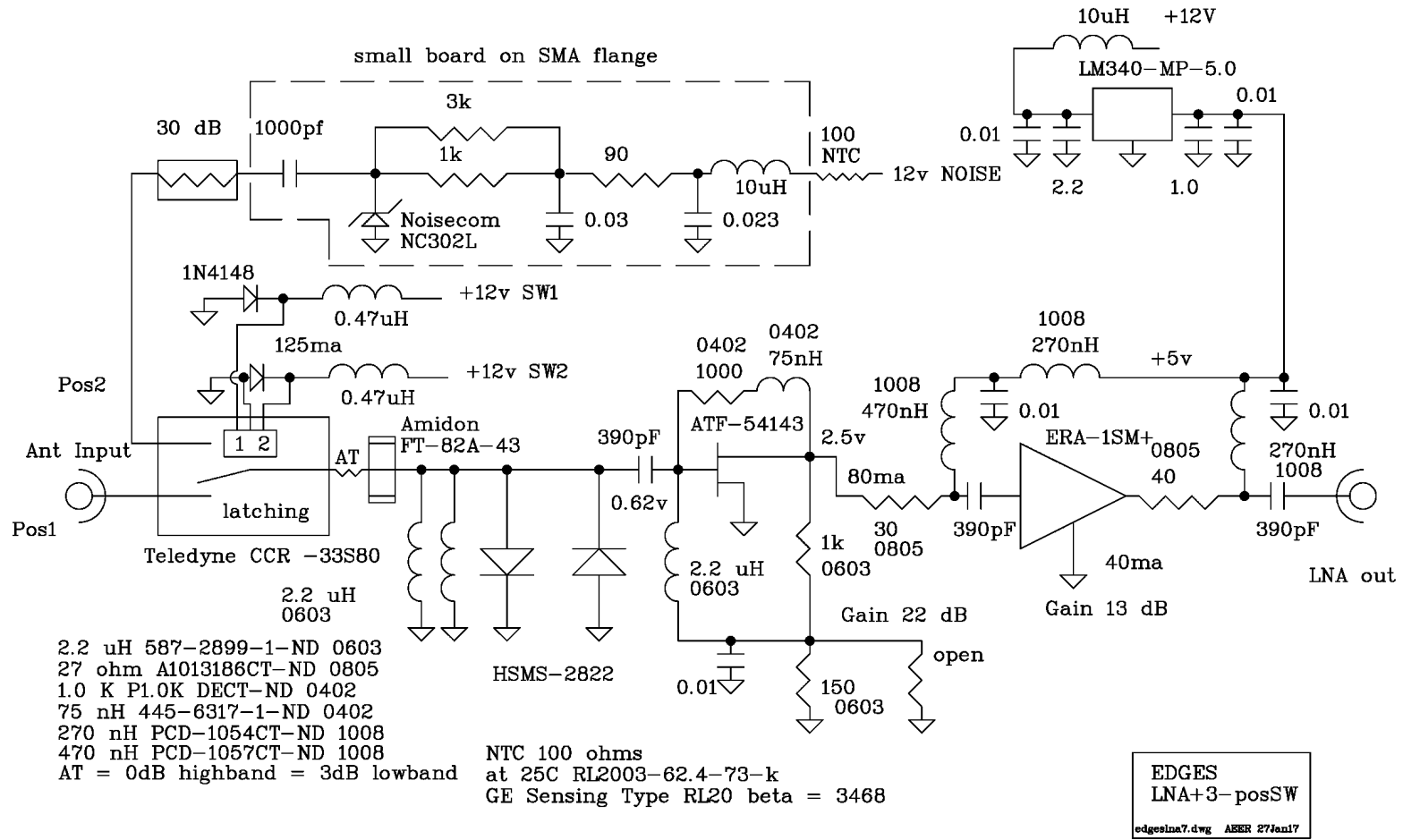


Figure 10. Updated receiver schematic for receiver in 2017.