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To: EDGES Group

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Subject: Estimates of isolation requirements for EDGES-3 electronics

1] Antenna box isolation to contain internal RFI

If the RFI power within the antenna box is -80 dBm for a 5 kHz bandwidth the isolation provided by the Faraday cage of the antenna box is

$$10log(1.38 \times 10^{-23} \times 10^3 \times 5 \times 10^3 \times 0.01) + 80 = -101.6\ dB$$

To hold the RFI below 10 mK in 5 kHz bandwidth

2] Isolation needed to keep gain change due to feedback at acceptable level

The factional voltage gain, g, due to feedback between last amplifier output and antenna is given by

$$g = 1 + \alpha\beta$$

where α is the voltage gain between antenna input and the output of the last amplifier and β is the feedback voltage gain. To keep the power gain variation due to feedback under 10 mK out of 3000 K

$$\beta = 3.3 \times 10^{-6}/2\alpha = 1.04 \times 10^{-9} = -179.6\ dB$$

for receiver gain of 64 dB. If the box isolation is -101.6 dB the output of last amplifier needs to have an isolation of more than 78 dB within the antenna box. For comparison with EDGES-2 the leakage of front end output cable into the antenna has to be less than -129.6 dB. In this case the shielding provided by the ground plane which covers the cable needs to be -29.6 dB for a cable leakage of -100 dB. In summary an isolation of about 180 dB with respect to a 0 dBm source is needed to keep the effects of RFI from the electronics and feedback into the antenna below 10 mK in a 5 kHz bandwidth. In order, to achieve this level of isolation another level of shielding is now being designed in which all the electronics with fast waveforms i.e. DC/DC converters, thermal control and Nuvo computer along with the backend RF amplifier will be placed in an “inner” shielded box. The VNA and its associated DC/DC converter can be outside this box, because no spectra are taken when the VNA is running. All the outputs from the inner box will be filtered by more than 80 dB and the ethernet connections for the laptop control and VNA will be converted to fiber before coming out of the inner box.

3] Test of box shielding

a) Simple theory

The leakage from a single slot without any conductivity between screws is approximately

$$20\ log(L/(\lambda/2))$$

Where L = slot length, λ = wavelength

For 6” long slots between screws this is – 20 dB at 100 MHz. With conductive material in the slot the added loss is approximately

$$20\ log(R/377)$$

Where R is the resistance across the slot and 377 is the wave impedance. For the 5,000 microohms per square inch of DTL-81706 standard the effective resistance across the slot is effectively $5 \times 10^{-3}/(WL/2)$ where W is the thickness of the metal for a leakage of about -50 dB for W = 0.25"

b) Measurements of front end box shielding

Figure 1 shows the initial layout of the EDGES-3 electronics in the antenna box with the top removed and the front-end box with cover removed. After some tests in a screen room it was found that the levels of RFI from the NUVO computer were high enough to require adding an inner shield. Figure 2 shows a Hammond 1550J box, the same part used for the frontend, with battery powered signal generator used for leakage tests. While the signal generator puts out a known power level of the 0 dBm (-8 dBm in photo as an attenuator was added) much of this power is reflected back into the generator so that all leakage measurements were made relative to the signal level measured by a spectrum analyzer with antenna about 1 m away from box with the box cover removed.

The results of the tests are given in Table 1.

Frequency MHz	Leakage dB	Conditions	Note
90	0	Box cover off – reference	
90	-10	Box cover with screws no gasket	
90	-40	Box cover on with screws	
90	-40	Box cover and only 3M 1126 Cu tape	
90	-42	Box cover and only Laird 903-1556-ND tape	
90	-50	Screws plus Cu 1126 tape	
90	-50	Screws plus Laird tape	
90	>80	Screws plus 903-1203-ND gasket	1
50	>75	Screws plus 903-1203-ND gasket	

Table 1. Results of measurements

Notes:

1. Laird 4053PA51H1800 2.3 mm Nickel_Copper foam with adhesive to vertical pins on cover

For all the tests in table 1 the spectrum analyzer was connected to a wire dipole about 2 m long. For a special test the spectrum analyzer coax input was connected across the slot with inner conductor to the lid and outer to the box. The leakage was then observed as the connection was slid along the slot. For all slots the leakage was a maximum in the middle of the slot between the screws and was too weak to observe at the screw locations. This shows that the leakage is limited by the conductivity of the gasket.

Useful reference:

Dr. Sergiu Radu, Engineering Aspects of Electromagnetic Shielding. Principal Engineer, EMC Design Sun Microsystems, Inc.

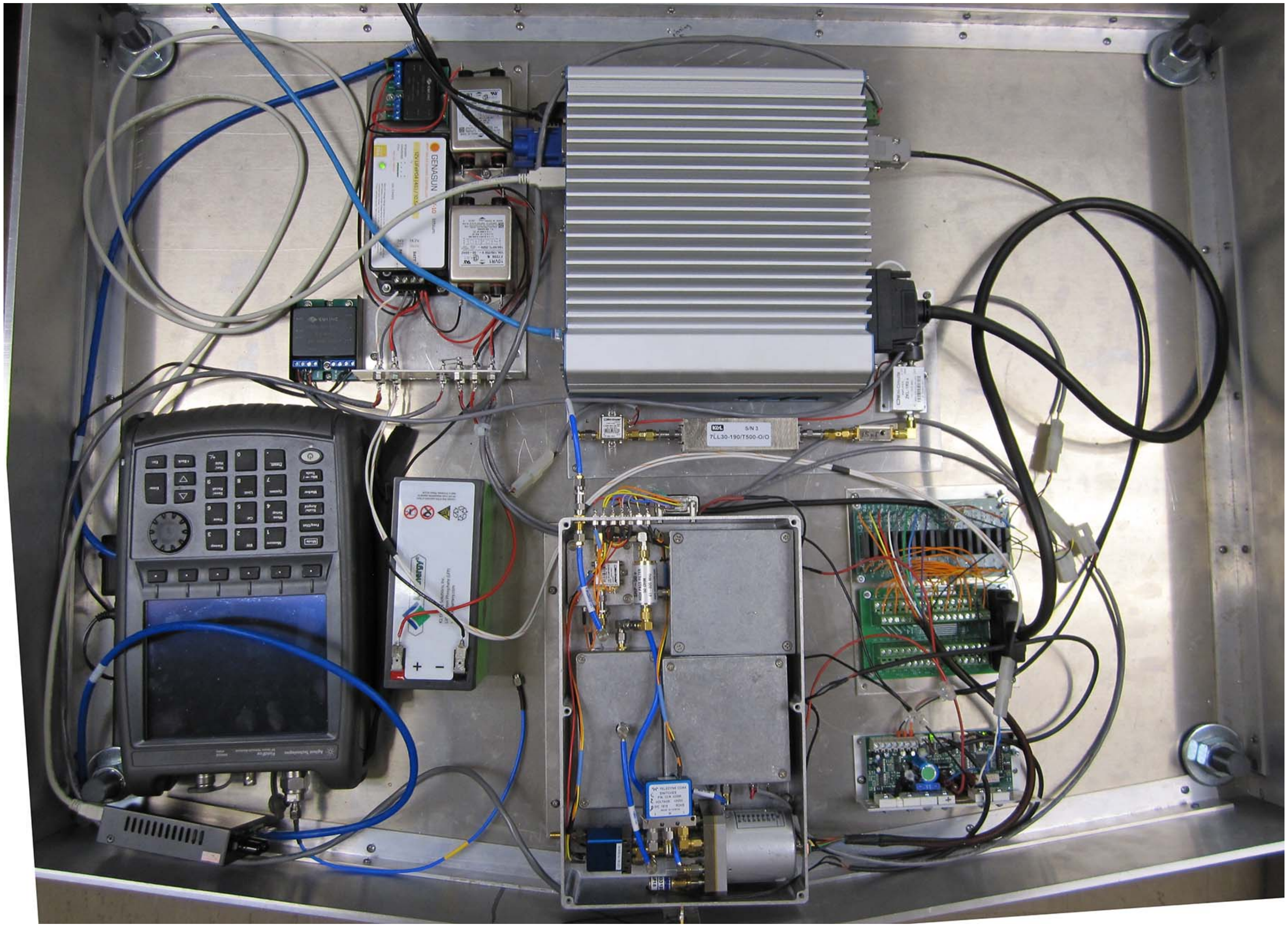

Figure 1. Initial test layout of EDGES-3

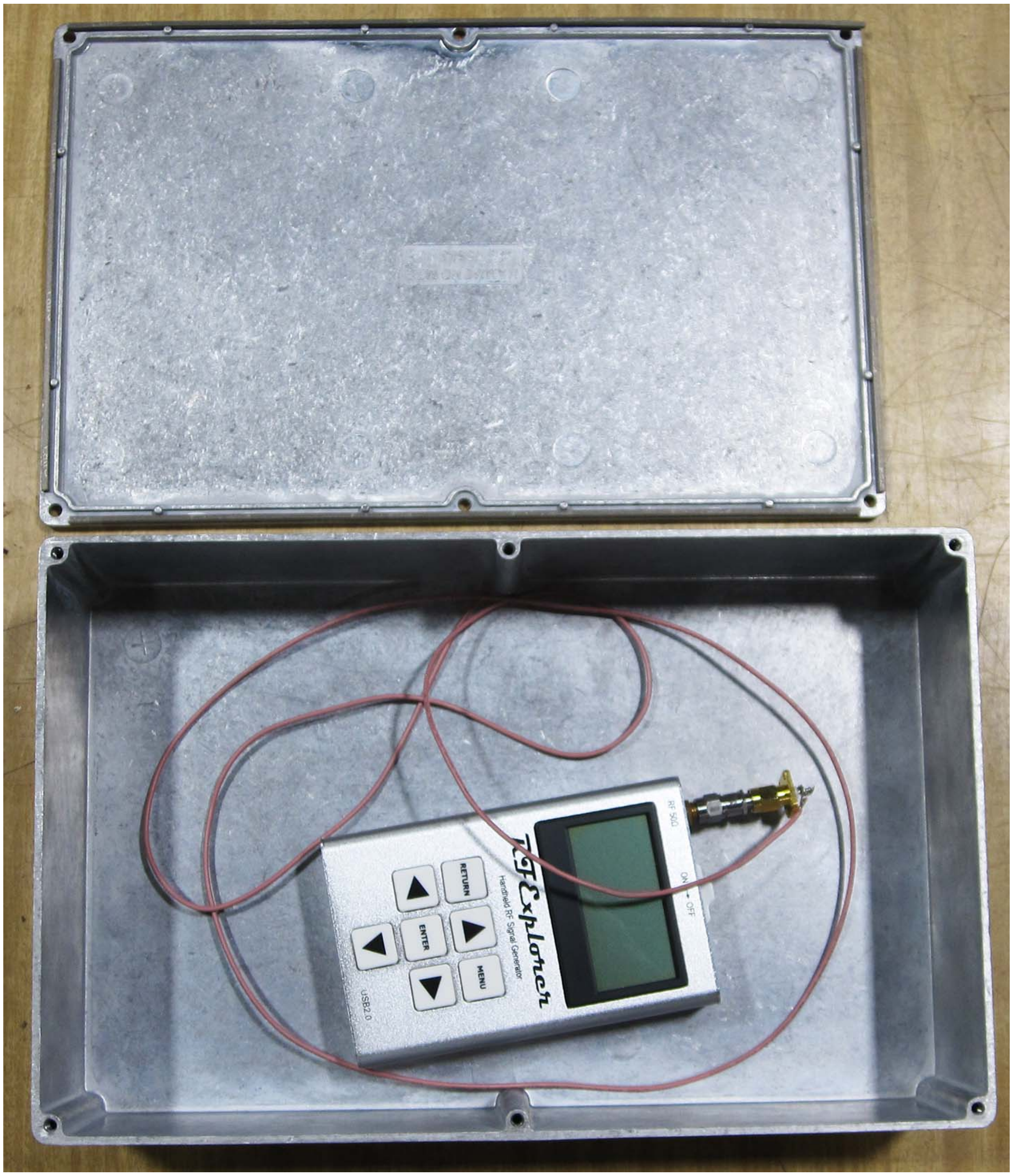

Figure 2. Set-up for tests of leakage from frontend box.