MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886

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Telephone: 781-981-5414
Fax: 781-981-0590

To: EDGES Group

From: Alan E.E. Rogers

Subject: Estimate of temperature gradient in EDGES receiver enclosure.

The EDGES receiver electronics is sealed in an aluminum box. The bottom of the box is held at 25°C using thermoelectric elements and a controller. The box (Hammond 1590Z235) is approximately 330×231×98 mm (L×W×H) with a lid which is approximately 330×231×20 mm. The average wall thickness is 4.9 mm. There is a rubber gasket between the box and its lid which is held on by 4 screws. In the field the box is below the ground plane with 12.7 mm of "pink" foam insulation between the top of the lid and the bottom of the ground plane. Additional pink foam panels of 330×118 mm are on the sides of the box. The front of the box is connected to the antenna and the rear to the cables which connect the receiver to the hut.

We model the "summer" condition by assuming that the air and ground plane temperature is 55°C. We start with the assumption that the box is at 25°C and estimate the temperature of the lid.

In order to estimate the thermal resistance of the connection between the lid and the box we rely on a laboratory measurement made on a similar box. In this test the lid was screwed down and "retorqued" the screws several times. The lid was heated to 45°C with a thermoelectric unit and held the bottom of the box to 35°C.

The temperature drop across the gap was 9°C. From this measurement the thermal conductance of the gap is estimated to be 10% of the conductance of the vertical heat flow along the sides of the box which is $204\times\left(2\times330+2\times231\right)\ \times4.9\times10^{-3}/98=11\ \text{W}/K$

Where the thermal conductivity of aluminum is 204 W/mK.

If we now assume the gap conductance is W/K and the "pink" foam conductivity is 0.03 W/mK the lid temperature will be raised by

$30\times0.03\times330\times231\times10^{-3}/\left(12.7\times1.1\right)=4.9^{\circ}C$ relative to the box.

In addition to the temperature increase of 1.1°C due to heat flow through the insulation between the top of the lid and the ground plane there will be heat flow to the sides of the box. For the insulated sides this will be

$30\times0.03\times2\times330\times98\times10^{-3}/12.7=4.6\,\text{W}$ and for the uninsulated front and back sides it will be

$30\times10\times2\times231\times98\times10^{-6}=13.6\,\text{W}$

Assuming $h_c=10\text{W}/m^2$ for the conduction to the stationary air. This added heat flow that will raise the temperature of the box half way up by about $0.5\times\left(4.6+13.6\right)/11=0.8^{\circ}C$ other sources of heat flow are from the antenna connection and radiative transfer to the uninsulated parts of the box. These are estimated to contribute no more than about 5 W.

In summary the dominant source of temperature gradient is most likely from the heating in summer or cooling in winter of the lid which in turn transfers heat to the internal electronics via the air inside the box. Engineering “fixes” to this problem under study are:

1] Replace “pink” insulation on top of the lid with a Vacuum Insulated Panel (VIP) to give a factor of 5 reduction in the heat conduction to the lid.

2a] Lower the thermal resistance across the lid to box by adding some soft copper plus silver thermal paste (conductivity ~ 2W/mK) to the gap.

2b] Seal across the gap in the lid with 2 layers of 1” wide 3.5 mil thick copper tape put on after tightening the lid as much as possible. Lab tests show that this lowers the thermal resistance across the cap by a factor of 5.

3] Improve thermal conduction between different parts of the receiver inside the box.

Tests with VIP (Thermalvisions.com 13.02×9.09×0.52 inch).

Using the following “stack-up” from bottom to top:

1] Thermoelectric element attached to bottom of the box
2] Hammond box
3] Hammond box lid
4] VIP panel
5] Large aluminum plate to simulate antenna ground plane.

With thermoelectric controller set to 50°C, the lid 49.5° and the aluminum plate 29° C.

The box lid was sealed with 2 layers of 1×2.5 mil copper tape. While the VIP is nominally of 0.52” thick the separation of the top of the lid and the aluminum plate was 0.63” without applying any pressure since a squeezing pressure is not recommended. In the field installation I suggest 4 layers of the tightly wound copper tape to reduce the thermal gradient across the gap.

In summary the combination of the VIP and the copper tape should reduce the temperature gradient to about 0.5° for a 20°C temperature difference between the receiver and the ground plane.