A Steady State Thermal Analysis of the Avionics Stack for the 3U Cube Satellite SPOC

Kaelyn Deal[1], Nir Patel[1], David Cotten[1,2]
[1]Small Satellite Research Laboratory, University of Georgia
[2]Center for Geospatial Research, University of Georgia

Overview

The mission of the University of Georgia's Spectral Color Ocean (SPOC) satellite is to acquire image data to monitor coastal wetlands, wetland biophysical characteristics, and near coastal ocean productivity. Inherent in this mission, SPOC will be receiving, processing, and transmitting crucial data for researchers at the University of Georgia while in Low Earth Orbit. Within the Avionics Stack of SPOC, the Ultra High Frequency Transceiver (UHF) and the S-Band Transmitter (both from Clyde Space) are responsible for the bulk of data collection and telecommunication. While all operations performed within the Avionics Stack require power, the two boards previously mentioned require substantially more than the rest, which gives rise to thermal energy concerns.

Analysis Approach

To address these concerns, the boards in the Avionics Stack were analyzed individually. The parameters of these analyses stemmed from the assumption that the boards are in a steady state. Simply put, a steady state analysis assumes the board's temperature data has approached a constant value after a theoretically infinite amount of time. Initially, 0% power efficiency was assumed, which yielded a worst case scenario where all power was being converted directly into heat. Under this assumption, if the boards maintained safe operating temperatures then at any power efficiency the boards could maintain a safe operating temperature. However, these results yielded extremely high values, so efficiency refinements were made. In addition the boards were analyzed in both a hot and cold state specified by 30 and -10 respectively. Moving forward, increased focus will be placed on the findings for the UHF and S-Band Transmitter.

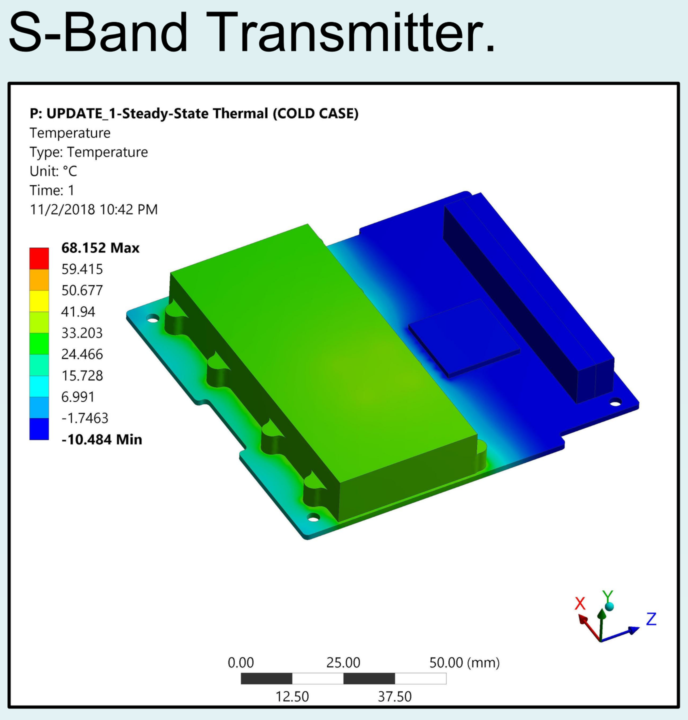

Figure 1: Picture left is the Cold Case of the UHF, including the enclosure seen in green.

Simulations

S-Band Transmitter

During peak operation, the S-Band Transmitter draws 4.83W of power, including a 5% contingency, and the temperature results from this can be seen in *Table 1* below. From inquiry, the efficiency of this board is quoted at 20%; so, the applied load is 3.84W, which is located on the small copper Radio Frequency Transmitter housed under the aluminium casing observed to your right in *Figure 4*. The casing, pictured in *Figure 3*, also contributes to an increase in thermal energy build up due to the added radiation within the housing enclosure.

Temperature [°C]	Cold Case	Cold Case (2-σ CI)	Hot Case	Hot Case (2-σ CI)
Minimum	-10.665	-21.665	30.158	19.158
Maximum	69.737	80.737	93.499	104.499

Table 1

Ultra High Frequency Transceiver

The UHF draws 5.355W of power, including a 5% contingency, and the effects of this load can be seen in *Table 2*. The efficiency of this board was quoted at a more generous value of 50%. Therefore, only 2.6775W is applied to this board. Much like the S-Band, the location of the applied load is associated with the small Radio Frequency Transmitter housed under the aluminium casing which you can observe in *Figure 2*. The UHF casing, pictured in *Figure 1*, behaves similarly to that of the S-Band casing, contributing to thermal energy build up due to the additional radiation within the housing enclosure.

Temperature [°C]	Cold Case	Cold Case (2-σ CI)	Hot Case	Hot Case (2-σ CI)
Minimum	-10.484	-21.484	30.191	19.191
Maximum	68.152	79.152	96.525	107.525

Table 2

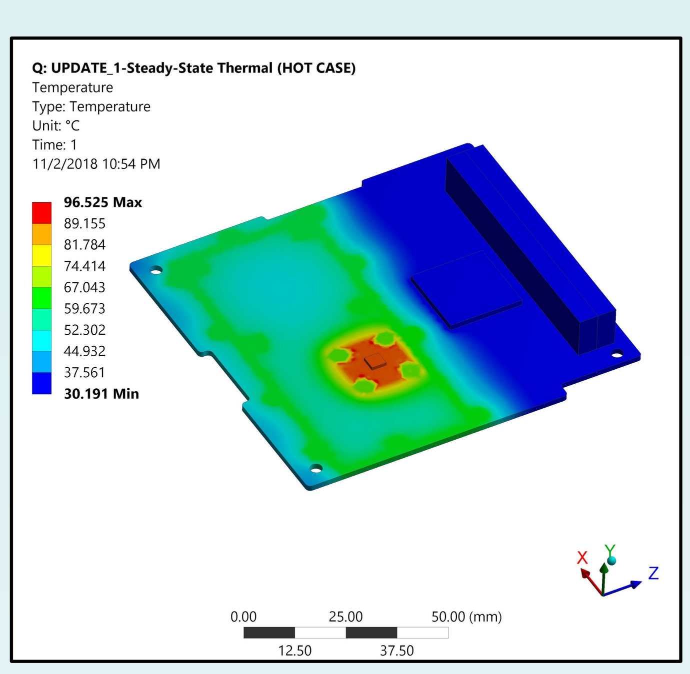

Figure 2: Pictured left is the UHF Hot Case without the enclosure for increased visibility of the Radio Frequency Transceiver.

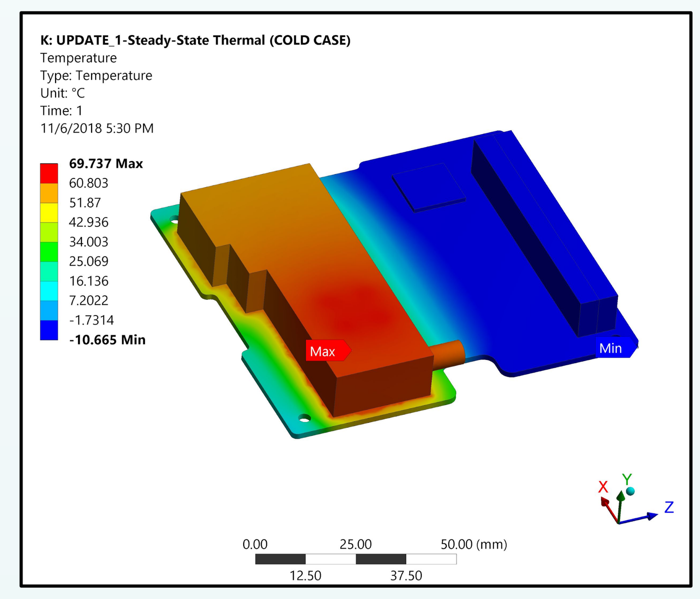

Figure 3: Pictured left is the Cold Case of the S-Band, including the enclosure seen in red and orange.

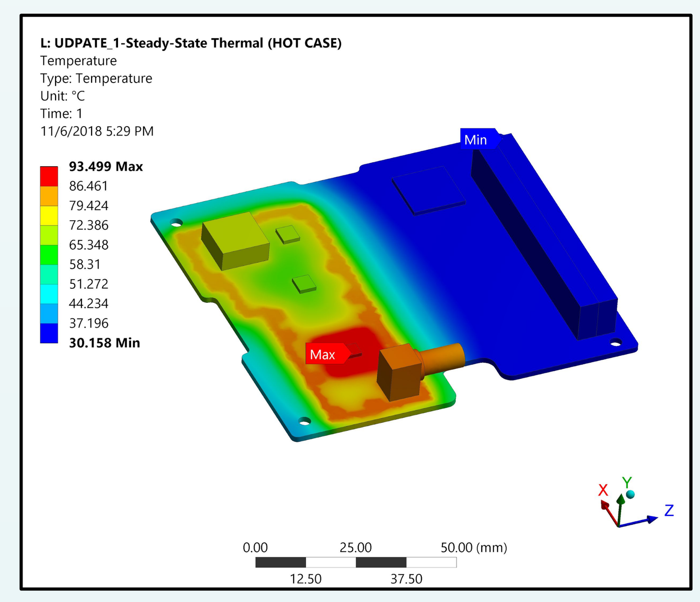

Figure 4: Pictured left is the Hot Case of the S-Band without the enclosure for increased visibility of the Radio Frequency Transmitter.

Discussion

Both the S-Band and UHF have a safe operating temperature range of -25°C to 61° C. During both the cold and hot cases, with or without the two sigma confidence interval of ±11°C, the UHF and S-Band do not operate within their allowable temperature ranges. These results indicate that a passive thermal control system, such as a thermal strap, will be needed to conduct some of this excessive heat toward a less thermally intense component such as the frame.

Future: Heat Straps | Simulations

Since these analyses, an inquiry has been made to the providers of these boards to attain even more accurate efficiencies. In effect, maximum temperature data has decreased. However, it still remains unsafe for both boards. In the future, the custom heat straps, including a thermal filler applied at the interfaces, will cater to the design constraints including, where the boards are placed in the Avionics Stack and their respective thermal needs. In addition, a full system simulation of the entire satellite will be performed in Thermal Desktop, which will ascertain how the components and their loads will interact with the harsh environment of Low Earth Orbit and with one another.

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Small Satellite Research Laboratory
Franklin College of Arts and Sciences
UNIVERSITY OF GEORGIA