High Power Microwave Absorber Boxes

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***Abstract*—This paper presents advancements in the development of efficient high-power microwave absorber boxes used during high power thermal vacuum (HPTVAC) test of spacecraft payloads. Multiple types of absorber boxes are shown, the pickup horn (PUH), generic pick up horn (GPUH), and Advanced Generic Pickup Horn (AGPUH). The paper describes how the absorber boxes have been modified from being able to handle 2 kW of power to 4 kW while maintaining the same or better functionalities. Also presented is how the AGPUH advancements have been applied to array applications.**

Keywords—Pickup horn, High Power Microwave Absorber Box, High power TVAC Test

I. Introduction

High power TVAC tests are performed to validate the thermal performance and functionality of the payload and spacecraft in vacuum, prior to launch. HPTVAC tests are typically conducted with full RF power to all transponder channels. The power radiated from the antennas must be fully absorbed to prevent damage to other antennas and sensitive flight hardware. Before the PUH and GPUH, there were two commonly used approaches to absorb the radiated high power. One approach uses a large absorber box to surround the entire antenna. Since it is not practical to have large absorber boxes around all the antennas on the spacecraft, multiple tests were conducted each requiring de-pressurizing and re-pressurizing of the TVAC chamber. This approach results in an expensive and very time-consuming HPTVAC test. With the other approach, the horns are de-mated from the feed chains and waveguides are used to route the high power to loads outside the TVAC chamber through RF transparent ceramic windows. These windows generally have poor return loss which together with the absence of the horns limit the accuracy of the payload tests.

The PUH, GPUH, and the AGPUH eliminate the problems associated with traditional approaches. Due to their small size and ability to absorb very high power with minimal RF leakage, several units can be used to perform high power tests of all payload transponders at the same time. These units also provide good return loss over a very broad frequency for any polarization which allows for more accurate performance measurements.

The following sections briefly describe the PUH & GPUH to introduce the advances made in the AGPUH. An efficient high-power absorber box for feed arrays that uses these advances is also described.

II. PUH Design

The PUH represented a very significant advancement in HPTVAC testing when it was first introduced. It is cost-effective, compact, and easy to implement. The PUH does not require any contact with flight horn, and does not require breaking vacuum to complete testing for all transponders in the payload. The PUH efficiently converts RF power into heat, which is transferred outside of the TVAC chamber, with minimal reflections back into the source, and low levels of leakage around the PUH.

The PUH consists of 4 slots as shown in Figure 1. Two larger slots at the center of the device receive most of the power while two smaller slots receive the rest. The slots are sized to make the PUH less sensitive to polarization. Each slot is filled with a wedge shaped high power absorber, and is thermally connected to a metallic web. The edge of the web is covered with absorber tips to minimize reflected power. Absorbed power is transferred from the loads to the webs before reaching the sidewalls of the housing where serpentine shaped passages allows coolant fluid to transfer thermal energy to a chiller unit located outside the TVAC chamber.

Each PUH is designed for a specific transmit frequency band. Return loss at Ku-band is typically > 19 dB. RF Leakage is < -50 dBc. Ku-Band PUHs have been used up to 2 kW of power. The unit measures 12.7 cm by 17.78 cm by 15.24 cm.

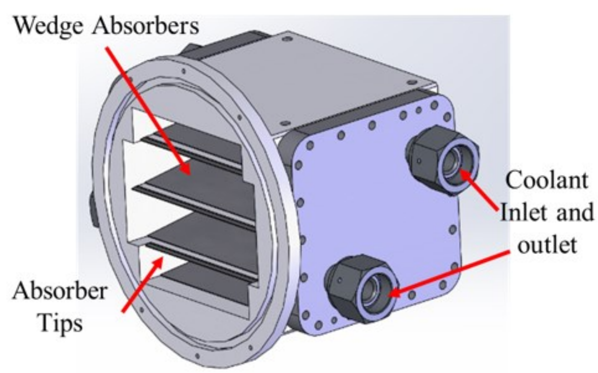

Fig. 1. Schematic of Pickup Horn (PUH)

To verify that the PUH can handle full power from the space craft a 300 W power simulation and test was conducted. Figure 2, shows the detailed thermal analysis including the serpentine cooling channels. The analysis shows that the maximum temperature of the load is -77 °C, with 300 W of input power. A 300 W power TVAC test was conducted and showed correlation with the thermal model.

To validate the return loss and leakage of the PUH a low power bench test was conducted. Figure 3 shows the setup of the bench measurement of the PUH. As can be seen from the picture the Horn aperture is not contacting the horn and the spacing has been set by a Teflon spacer so it will not damage the horn.

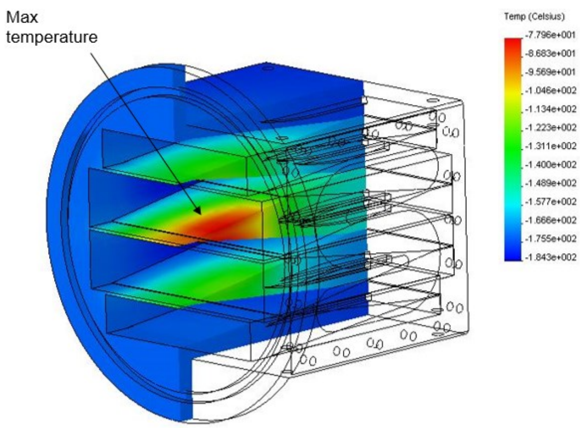

Fig. 2. Simulated Thermal Model for PUH

Fig. 3. PUH Bench Measurement

Figure 4, shows results from the test conducted on the PUH, the plot shows the horn return loss as a dashed line, and the return loss from the setup shown in Figure 3 as the solid line. As seen from Figure 4 the absorber box has only a small impact on the horn return loss, of approximately -30 dB in level.

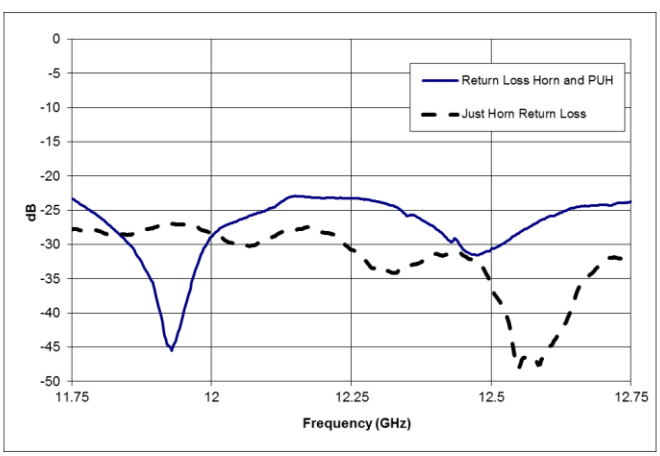

Fig. 4. PUH Return loss

III. GPUH Design

The GPUH, Figure 5, functions like the PUH with some improvements. It operates over a much wider bandwidth covering more than three octaves over X, Ku and Ka bands and provides about 5 dB return loss improvement. The slots in the GPUH are designed to make it less sensitive to polarization with better return loss and to cover the wider bandwidth. The GPUH supports vertical, horizontal, left and right hand circular polarizations. Like in the PUH, the central slots in the GPUH receive most of the power with the outer slots receiving the rest. Tip loads are also used to cover the cooling webs. The cooling mechanism is the same as the PUH and the GPUH can also absorb up to 2 kW of power.

Return loss for the GPUH > 25 dB and RF leakage is <-55 dBc. The unit measures 18.03 cm by 29.21 cm by 22.23 cm.

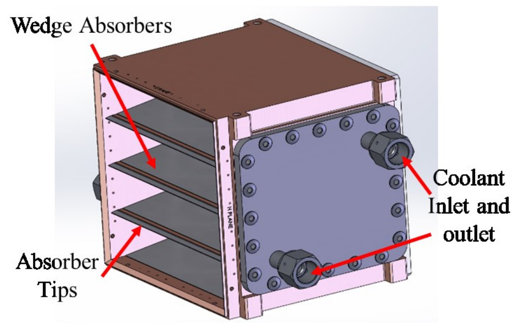

Fig. 5. Schematic of General Pickup Horn (GPUH)

The GPUH was tested with the same test setup as the PUH, as shown in figure 3. This PUH shows better return loss and polarization insensitivity, as can be seen from Figure 7. The horn return loss performance by itself is shown as a dashed line, and the return losses for horn polarizations from 0° to 90° are shown as solid lines. The impact on return loss is small for all polarizations tested. The GPUH impacts the performance by approximately a -28 dB level.

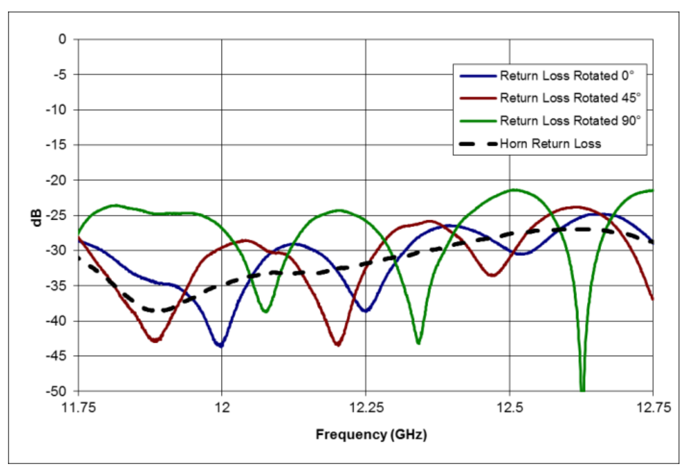

Fig. 6. GPUH Return loss

IV. AGPUH design

The AGPUH, Figure 7, increases power absorption from 2 kW to 4 kW while still maintaining a similar envelope. It is like the GPUH in that it operates over a very wide bandwidth, supports vertical, horizontal, left and right hand circular polarizations, has low RF leakage, and provides good return loss. To increase power absorption, the slots in the GPUH have been replaced with high power absorber wedges and a single piece cooling plate with internal cooling channels. The absorber wedges provide good return loss while efficiently absorbing the extremely high power from the radiating horn. Like the PUH & GPUH, the central wedges receive most of the power. To increase power handling and more effectively transfer the heat out of the box, cooling channels are placed close to maximum power density locations to reduce thermal transfer path-lengths. The absorber wedges are recessed from the end of the box to reduce leakage and to allow the radiating horn to be placed away from the tips of the high-power absorbers.

Return loss for the AGPUH is > 25 dB and leakage is <-55 dBc. The unit measure 20.32 cm by 24.74 cm by 20.32 cm.

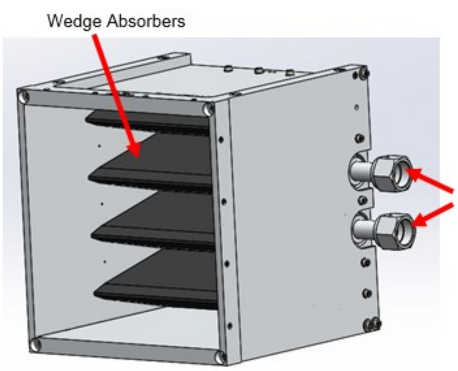

Fig. 7. Schematic of Advanced Generic Pickup Horn (AGPUH)

To show power handling performance of the AGPUH, a RF thermal model was created, using the same techniques utilized in the PUH. Figures 8 and 9 show that the analysis and measurement have high level of correlation.

Figure 8 show the RF thermal model. The maximum simulated value sown is 262.1°C. This model of the thermal performance was done utilizing the same tools as what was used for the PUH.

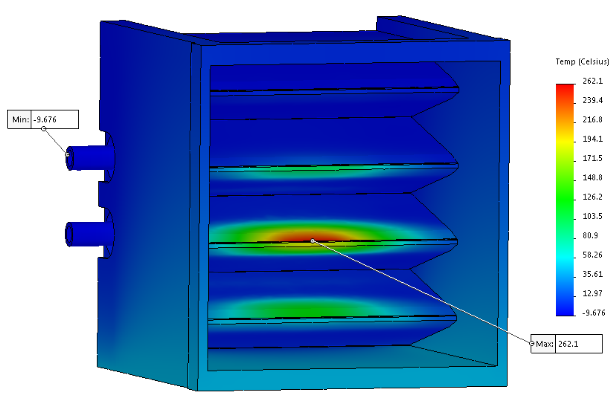

Fig. 8. Simulated Thermal Model for AGPUH

Figure 9 shows the TVAC test result which correlate very well to the simulation shown in Figure 9. The measurement was made using a forward looking infrared instrument, and infrared transparent windows on the TVAC chamber. Maximum measured value was 258°C.

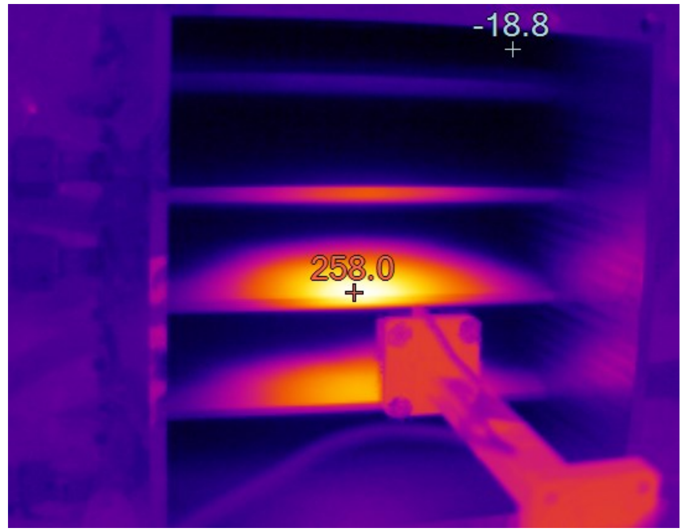

Fig. 9. Simulated Thermal Model for AGPUH

A low power RF test was also performed on the AGPUH to show the impact of the AGPUH on horn return loss. As shown in Figure 10 there is a small impact from the AGPUH, of approximately -30 dB level. The figure shows the horn return loss as a dashed line, and the return loss from the AGPUH and horn as the solid line.

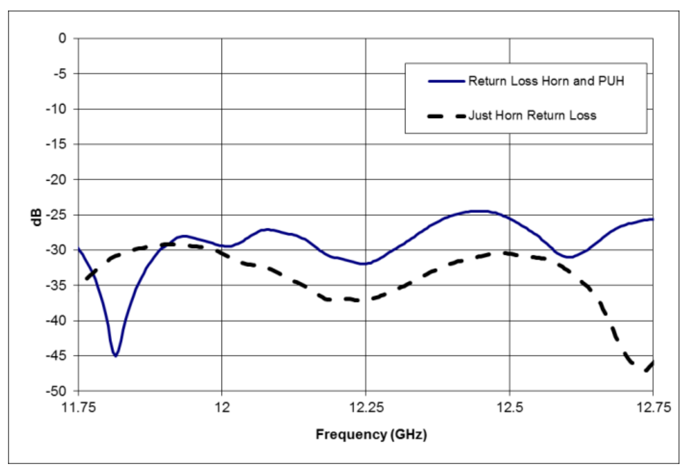

Fig. 10. AGPUH Return loss

V. HIGH POWER ABSORBER BOXES FOR FEED ARRAYS

The improvements made for the AGPUH were also implemented on high-power absorber boxes for feed arrays. The size of the box was chosen to accommodate a certain number of feed elements. The design was such that the feed locations can be arbitrary within the chosen envelope. The design provides wide bandwidth performance, good return loss, and is not sensitive to polarization like the AGPUH. Since power is distributed among several elements, power density is not as high as for the AGPUH or GPUH. This allows for a simpler cooling mechanism located at the back of the absorber box and allows the design to be modular to accommodate very large arrays if required. The unit shown in Figure 11 was designed to handle 4.8 kW total power from a feed array with 12 elements. As for the AGPUH, precision CAD was used for RF and thermal design. Much higher power is possible through appropriate thermal design. CMI has supplied high power absorber boxes at Ka and S bands.

Return loss for the unit shown in Figure 11 is > 25dB and leakage is <-55dBc.

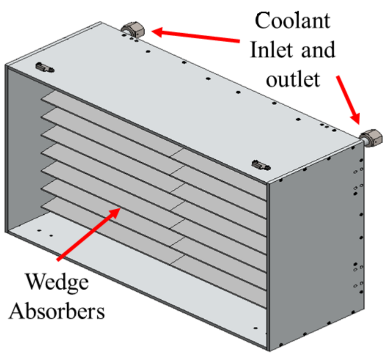

Fig. 11. High Power Absorber Box for Feed Arrays at Ka-Band

To verify thermal performance a RF thermal model was created similar to what was shown in figure 8 and tested in a TVAC chamber to show correlation. A similar level of correlation was shown on the array box.

A low power RF test was performed on the array box to show the impact of the array box on horn Return loss. As shown in Figure 12 there is negligible impact from the array box. The figure shows the horn return loss as a dashed line, and the return loss from the array box and horn as the solid line.

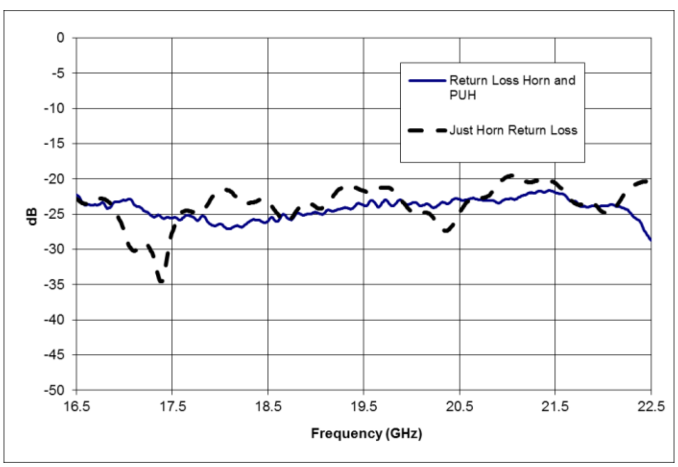

Fig. 12. Array Box Return loss

VI. SUMMARY

The AGPUH has significant improvements on the GPUH that increased power absorption from 2kW to 4kW while maintaining all other features such as good return loss, low RF leakage, wide bandwidth, polarization insensitivity, low cost, and a very small envelope.

This significant improvement was achieved with the use precision RF CAD. Loads were designed for optimum return loss over a very wide bandwidth while minimizing power density. Thermal properties for the different materials were experimentally characterized and used in the thermal design and analysis. Performances of the AGPUH were successfully validated by test using CMI TVAC chamber with a high level of correlation between simulation and measurement.

A high-power absorber box has also been described for feed arrays which can be used for very large arrays if required due to its modular design. This also showed a high level of correlation between measurement and simulation.

ACKNOWLEDGMENT

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