Cooling of Under Radome COTM Terminals with Forced Air Heat Exchanger

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Comms-on-the-move (COTM) terminals are typically protected against the environment by radomes that cover and protect the entire unit. This has the effect of trapping latent heat produced internally by RF components. Climate control systems such as air conditioners are often too large and also consume considerable DC power. EM Solutions has developed a forced air heat exchanger that integrates with a COTM terminal and can provide sufficient cooling for a medium power Block Upconverter.

Nomenclature

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\begin{align*}
COTM &= \text{Communications on the Move} \\
SATCOM &= \text{Satellite Communications} \\
BUC &= \text{Block Upconverter}
\end{align*}
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I. Introduction

As the need for higher speed communications through SATCOM devices increases, so too does the need for higher powered amplifiers. As a consequence, the requirement of cooling systems to dissipate excess energy becomes significant. For systems situated under radomes, dissipating excess energy can become challenging without compromising the environmental sealing integrity required for constant outdoor use.

With environmental sealing a non-negotiable requirement for most outdoor terminals, a solution is required whereby the heat produced within the radome can be transferred to the outside world without simply using a duct or vent. Although air-conditioner units can be suitable solutions, they come with an envelope, mass and power consumption penalty.

EM Solutions has developed a heat removal process for a COTM terminal in the form of an air-to-air heat exchanger which adequately dissipates approximately 200W of energy without the need of an air-conditioning unit. This has been demonstrated on an X-band terminal intended for land mobile applications.

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II. Heat Sources within the COTM Terminal

SATCOM terminals are generally constructed from any number of smaller sub-assemblies. In order to get the best product performance and reliability, the sub-assemblies themselves are usually environmentally sealed, and can often be seen as a stand-alone product in their own right.

The single largest source of heat within these sub-assemblies is the Block-Upconverter or BUC. An example of a typical BUC is shown in Figure 1.

![Figure 1 - EM Solutions BUC](image)

Internally, the BUC has a number of Gallium Arsenide GaAs or Gallium Nitride GaN packaged semiconductor devices which produce RF output power, but also produce waste heat. A GaAs BUC that produces for example, 6-8 watts of linear power, due to the poor DC efficiency of its GaAs devices (approximately 5%) will consume approximately 150-200W of DC power.

Fully environmentally sealed, the BUC has its own cooling system with heatsink fins located underneath the heat sources, and high power fans sweeping across the fins to promote the best heat transfer. The dilemma is that whilst this process is suitable when the BUC is located externally in free air, the air heated by the fins has no escape when the BUC is situated under an environmentally sealed radome.

A. Climate Control Unit

In some situations it is possible to use a climate control system such as an air-conditioning unit. For COTM terminals an air-conditioner is more practical in the marine environment where size and power consumption are less critical. A typical unit that produces 1 kilowatt of cooling will have a size penalty envelope of 620mm x 450mm x 150mm high, a mass penalty of 25kg and more significantly a power consumption of 450W.

For a land COTM platform these are significant issues that can prevent their use.
An alternative approach was needed that could be elegantly integrated into the existing terminal without dramatically increasing the physical size or the DC power consumption of the terminal.

In the past, EM Solutions had built existing terminals with a fabricated sheet metal base which were either vented to the environment or cooled via an air conditioner unit.

An alternative solution to remove the heat is that rather than using a single sheet metal design, a series of machined aluminium layers separated by air are built up and joined, creating a double channel void for air to pass through. The top channel is directly linked to the inside of the radome and circulates fan-forced air through its channel and inside the terminal under the radome. This air is never recirculated to the external environment; rather, it circulates internally.

Heat dissipation is aided with heat sinking folded fins situated within the channelized structure itself. The channel below does not access the inside of the radome area, rather the fins transfer the heat from the hot air passing through the top channel into the bottom channel through which cooler external air is circulated. Again fan-forced air finally moves the heated air within this channel away from the unit without affecting the environmental sealing integrity of the volume inside the radome.

From Figure 3 it can be seen that the air under the radome is circulated and forced into the internal side the COTM base which is one half of a heat exchanger. This heat is then removed to the environment, by passing ambient air through the second half of the heat exchanger.
A. Design Process

The overall layout was designed to fit an appropriate base for the terminal. A simulation process known as computational fluid dynamics (CFD) was used to model the airflow through the heat exchanger. This software allows the virtual simulation of airflow and thermal measurements to predict which design elements will achieve the best results.

With spatial and mass requirements being precious to the design, thin folded aluminium fins were found to be the best solution for the heat sinking fins. These fins can be far thinner than any traditional machining process can produce, and as expected, with a greater numbers of fins comes an improved thermal transfer performance.

Folded fins are available in many different pitches and variations, and with the use of these fins comes the concern of pressure drop within the channel. The greater the frequency of fins, the larger the heat dissipation, but this also causes an increase in the obstruction for air to pass through the finned channels.

With the most common types of folded fins being straight folded and lanced-offset, the CFD simulations were able to predict that the lanced-offset fins would produce the most desirable results. The heat exchanger used 20mm lanced offset fins with a pitch of 12 fins per inch. Fans were selected to accommodate the pressure drop produced by these fins.
B. Manufacture Process

A five layer assembly was designed for the heat exchanger. The middle layer (number 3 in Figure 5 - Heat Exchanger Layers) is the main body in which the fins for the top and bottom channels are fixed in place. The second and fourth layers are six sets of folded fin sections for each of the top and bottom channels. The first and fifth layers are covers for the fins which will create the enclosed channels for circulating air.

The method by which these parts are bonded is known as vacuum brazing. Rather than welding, which involves melting the work pieces themselves to join, vacuum brazing joins multiple metals together by flowing a filler metal with a lower melting point than the work pieces into the joints. This process offers cleaner joints and higher strength bonding than traditional welding techniques.

Performed in a vacuum chamber, temperature uniformity (as opposed to heating at spots) is maintained across the work piece which significantly improves the thermal and mechanical properties of the work parts.

Though expensive, the work pieces reach the brazing temperature all at the same time, meaning all joints can be made simultaneously, and on completion, no further fasteners are required. The final assembly is shown in Figure 6.

Figure 5 - Heat Exchanger Layers

![Figure 5 - Heat Exchanger Layers](image)

Figure 6 - Manufactured Heat Exchanger

![Figure 6 - Manufactured Heat Exchanger](image)
IV. Testing

The forced air heat exchanger base was tested and an Efficiency v Flow Rate Curve produced in Figure 7. This was achieved by varying the thermal loads under the radome for various fan flow rates.

![Heat Exchanger Efficiency Curve](image)

**Figure 7 - Heat Exchanger Efficiency Curve**

Figure 8 shows a forced air heat exchanger that has been vacuum brazed. The terminal can accommodate axial cooling fans that produce a flow rate of 25CFM. Therefore from the efficiency curve, for a terminal thermal load of 180W, the temperature rise in the heat exchanger is 20°C. Based on the equipment in the COTM, this temperature rise is acceptable.
V. Conclusion

The newly developed forced air heat exchanger has thermal and mechanical properties to ensure EM Solutions terminal designs for the future. It successfully reduces temperature rise, whilst maintaining the environmental sealing integrity that is critical to satellite communications terminal performance. Mechanically, with its low profile and fully internal design structure, it brings the potential to create smaller envelope and lighter terminals. It lowers power consumption since only compact fans are required, and at the same time supports a reduction in size and mass.

References
