

High-Power Liquid Cooling Architecture for Radar Subarray Electronics

At a Glance

Advanced Thermal Solutions, Inc. (ATS) conducted a CFD-driven design and optimization of a liquid-cooled cold plate system for a high-power ultrawideband radar subarray platform. The architecture was developed to cool amplifier and analog cards across a wide ambient range using a 40/60 propylene glycol-water mixture.

CUSTOMER OVERVIEW

The customer was developing a high-power radar subarray platform with amplifier and analog cards integrated into a liquid-cooled architecture (Figure 1). The design needed to support dense power electronics, a wide environmental range, and a coolant mixture suited to the mission profile.

- Radar platform with amplifier and analog card cooling requirements
- Multiple high-power modules operating within tight board temperature limits
- Series-connected cold plates with manifold integration

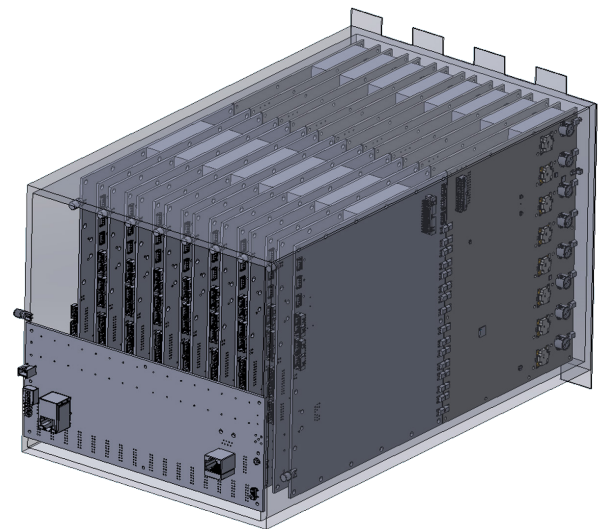


Figure 1. ATS Provided CFD Simulation and Design for a Fluid-Based Cooling System on a Radar Subarray

CHALLENGE

The system had to cool 16 high-power amplifier cards, with scenario loads up to 75 W per module, while maintaining board temperatures below an 85°C threshold and working toward a 70°C objective. The design also had to balance wide ambient conditions, glycol-based coolant constraints, and acceptable pressure drop in a manufacturable cold plate architecture.

Thermal challenge:

- 16 high-power amplifier cards
- Up to 75 W per module in the scenario basis
- Board temperature threshold: 85°C
- Board temperature objective: 70°C
- Wide ambient range from -18°C to 46°C
- Series-connected cold plates with manifold integration

The challenge was not simply adding cooling capacity, but creating a balanced thermal architecture that reduced hot spots and improved temperature consistency within a constrained package.

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METHODOLOGY

ATS used CFD and system-level flow modeling to develop and validate a dual tubular cold plate solution for the amplifier and analog cards. The work focused on geometry, pass count, manufacturability, series flow behavior, and the interaction between pressure drop and available pump performance.

Cold Plate Engineering Approach

- Designed dual tubular cold plates for amplifier and analog cards (Figures 2 & 3)
- Used standard 0.25 inch tube geometry with 6.35 mm OD
- Applied multi-pass serpentine routing optimized for manufacturability
- Integrated push-to-connect manifold design with series-connected cold plates

Key Investigation Areas

- Pressure drop versus heat transfer coefficient tradeoff
- Low-power and high-power flow rate requirements
- Amplifier and analog card cold plate pass-count optimization
- System-level pump curve interaction and available flow
- Validation against ATS iCDM-20 Cooling Distribution Module performance data

This approach validated the design against both temperature targets and realistic system flow capability.

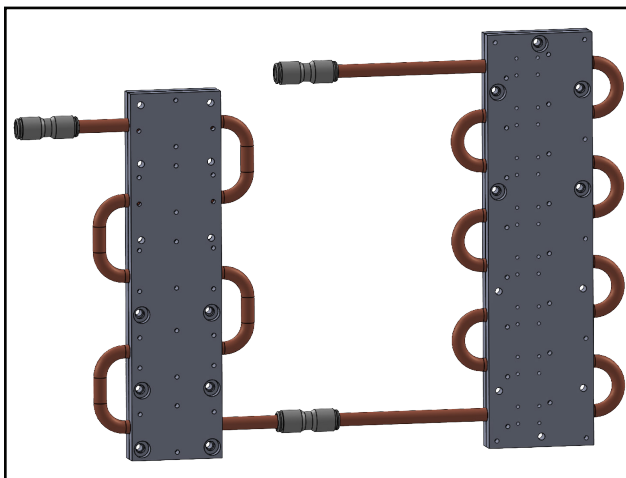


Figure 2. CFD Simulation of In Series-Connected Tubular Cold Plates

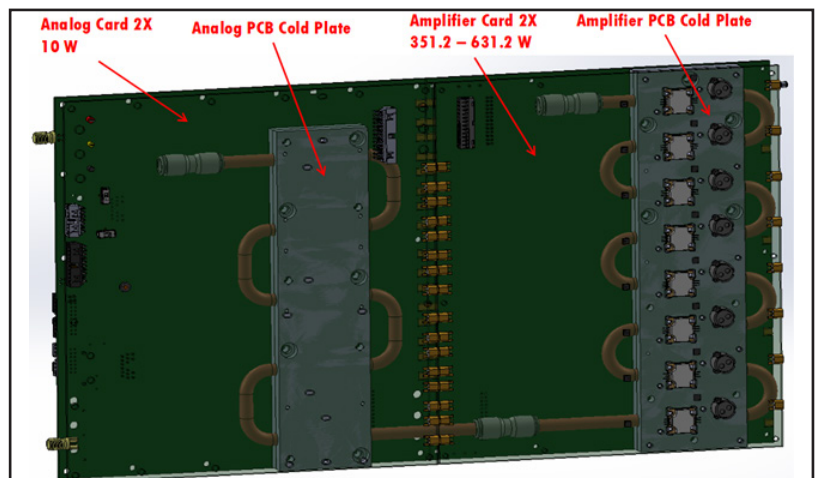


Figure 3. Cold Plate in Position on Analog and Amplifier Cards. The Amplifier Card was the Main Contributor to the System's Power Dissipation. The Cold Plate on the Amplifier Card has 8 Passes and 7 Bends, While the Analog Card CP has Just 5 Passes and 4 Bends

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SOLUTION

ATS developed a standardized tubular cold plate architecture using 0.25 inch tubing and multi-pass serpentine layouts tailored to the amplifier and analog cards. The amplifier card cold plate used 8 passes and 7 bends, while the analog card design used 5 passes and 4 bends. The plates were integrated in series with manifold connections and optimized against both hydraulic resistance and thermal effectiveness.

- Adopted liquid cooling after eliminating air cooling as impractical
- Designed dual tubular cold plates for amplifier and analog card groups
- Standardized on manufacturable 0.25 inch tube geometry
- Optimized pass count and serpentine routing for heat transfer and pressure drop balance (Figures 4 & 5)
- Integrated manifold connections for series cold plate operation
- Validated design against realistic pump and CDU performance data

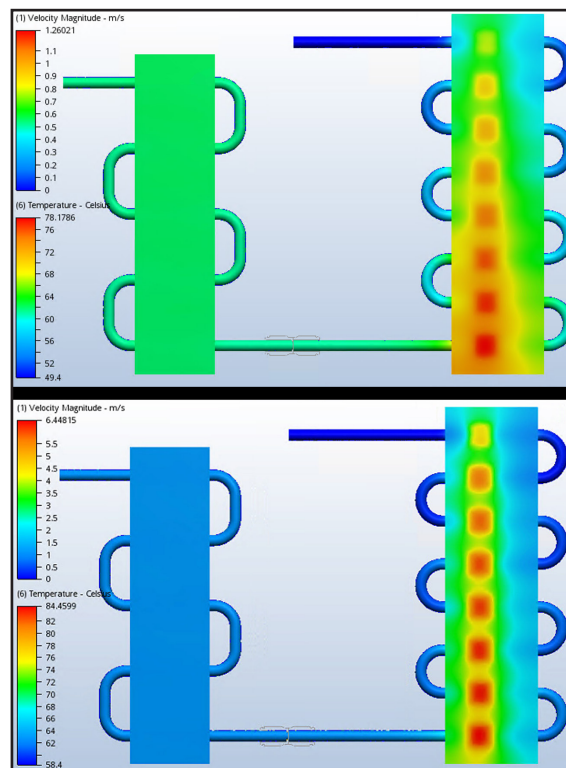


Figure 4. CFD Simulation Results at (top) Low Power with a 2 GPM Flow Rate, and (bottom) High Power with a 12 GPM Flow Rate

The final architecture provided a scalable, manufacturable solution for high-density radar electronics cooling under both low-power and high-power operating conditions.

CP Flow Rate, V_{in} , GPM	System flow rate, GPM	Amplifier Power, W	Average CP Surface Temperature, T_{pcb} , °C	Maximum Amplifier Case Temperature, T_{amp} , °C
0.25	2.0	40	65.1	75.9
0.38	3.0	40	63.0	72.1
0.50	4.0	40	62.2	70.4
0.63	5.0	40	61.7	69.4

CP Flow Rate, V_{in} , GPM	System flow rate, GPM	Amplifier Power, W	Average CP Surface Temperature, T_{pcb} , °C	Maximum Amplifier Case Temperature, T_{amp} , °C
0.56	4.0	75	73.6	88.6
0.62	5.0	75	72.2	86.3
1.25	10.0	75	68.7	80.6
1.5	12.0	75	67.3	78.8

Figure 5. CFD Simulation Results for (top) Low Power and (bottom) High Power Performance of the Combined Cold Plate for Cooling the Analog and Amplifier PCBs.

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RESULTS & DATA

The optimized liquid cooling architecture met both threshold and objective performance targets across the evaluated operating conditions.

Low-power performance:

- Scenario basis: 40 W per amplifier
- Board temperatures below 70°C achieved at flow rates of 2 GPM or greater
- Pressure drop ranged from approximately 1.8 psi to 7.3 psi depending on flow

High-power performance:

- Scenario basis: 75 W per amplifier
- 70°C objective achieved with upgraded pump capacity at 10 GPM or greater
- Pressure drop ranged from approximately 24.7 psi to 35.2 psi depending on flow

The results showed that ATS successfully coupled thermal and hydraulic optimization, ensuring that the cold plate geometry was both thermally effective and compatible with available pump and system flow capability.

Thermal engineering outcomes:

- Integrated CFD and system-level flow modeling
- Balanced pressure drop against heat transfer performance
- Standardized tubular cold plate geometry for faster manufacturability
- Validated design using ATS iCDM-20 performance data
- Established a scalable architecture for high-density power electronics

ANALYSIS & CONCLUSION

This study shows that successful high-power liquid cooling for radar electronics requires coordinated optimization of cold plate geometry, manifold layout, pressure drop, and available pump performance.

- Air cooling was ruled out based on impractical pressure and geometry demands
- Liquid cooling success depended on both thermal and hydraulic optimization
- Series-connected cold plates required careful manifold and flow planning
- The final design supported scalable deployment in dense radar power electronics systems

ATS delivered a CFD-validated, manufacturable liquid cooling architecture that met performance targets while preserving a practical design path for radar subarray electronics.

Take control of your thermal performance with expert analysis and design services, contact ATS to speak with our engineers and start optimizing your system today.

