Passive cooling to optimize performance of radio telescope amplifiers using SRI's Self-Cooling Paint™

Results of an independent field test

Radio telescope amplifiers must stay cool to optimize performance

The Owens Valley Radio Observatory (OVRO) is a radio astronomy observatory owned and operated by California Institute of Technology (Caltech) near Big Pine, CA. The site director was seeking a passive radiative cooling solution as Caltech was preparing to build an array of 2000 radio telescopes. The radio telescope array is comprised of two thousand antennas, each equipped with a low-noise amplifier (LNA) operating in the 0.7—2.0 GHz band and enclosed in a 6061 aluminum box with a surface area of about 0.41 square feet. The amplifiers will be installed near the focus of the antenna reflectors and exposed to direct sunlight and the full range of ambient temperatures. Optimal antenna performance relies on high sensitivity and low noise output of the LNAs which depends on minimizing the internal temperature. A rule of-thumb for the lifetime dependence of electronics on temperature is that a 10°C increase halves the lifetime. Keeping the temperature as low as possible is therefore an important goal. Whereas active cooling could be implemented, this would require additional electronics, as well as require maintenance and repair, increasing costs. The conclusion was to look for a simple passive cooling solution.

SOLUTION

SRI Self-Cooling Paint is a passive radiative cooling solution that does not require any power or electricity and can cool down any sky-facing surface by 5-8 °C (8-12°F) below ambient air temperature*, and 15-30 °C (20-50 °F) below ambient on an uncoated surface.**

The significant achievement of sub-ambient surface temperatures is realized by engineering the paint coating to achieve high solar reflectance with high infrared emittance in the atmospheric transparency window.

APPROACH

The test was carried out using a rig with two prototypes of the microwave feed used to collect the antenna signal, each with two dummy LNAs. The rig was set up outside at the Owens Valley Radio Observatory.

The dummy LNAs use the same aluminum enclosure as the operational LNA devices, but with the operating amplifier circuit board replaced with a thermal load circuit board the simulated the heat dissipation of an operating amplifier. The dummy LNA enclosure is outfitted with four temperature sensors located: (1) on the thermal load circuit board, (2) in the air space in the enclosure cavity (3) on the interior surface of the top of the enclosure (sun and sky-facing side) and (4) on on the interior surface of the bottom of the enclosure (shaded and not sky-facing side). Each sensor had a nominal resistance of 10 kΩ at 25°C and was configured as one element of a resistive divider in series with a fixed 10 kΩ resistor. The divider was fed from the same 5 V that powered the heating resistors, and the division point was monitored to derive the temperature.

Monitoring was performed using a LabJack T8 connected to a laptop running a purpose-built LabVIEW program to view and record the data. A cup anemometer and a temperature/ humidity sensor were also used to measure external conditions.

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APPLICATION

The images to the right show the radio telescope on which the signal feeds and LNAs will be mounted, the four dummy LNAs with sensors (two painted with the SRI paint and two unpainted as references), and two views of the test rig.

TEMPERATURE MEASUREMENT

Temperature recording began in April 2025 and continued through the summer months. Several variations of configuration were assessed to understand the cooling effects of the paint. Two of the dummy LNAs were painted with Self-Cooling Paint (LNA1 and LNA3), and two were initially unpainted (LNA2 and LNA4). Additional measurements were taken where one of the unpainted units (LNA4) was painted with a commercially available acrylic-based cool paint. All test units show similar behavior, reflecting the increasing heating during the day and cooling at night.

RESULTS

According to Caltech, "[The thermal] trends were as expected. Lower temperatures are observed for the painted blocks at all times, with greater cooling evident during the day. There is possibly evidence for variations during the day that depend on the angle of incidence of the sun on the amplifier cases. Variations on timescales much less than a day are typically associated with either wind or cloud cover. These are seen in both the temperatures and the temperature differences."

Plots at right display sensor temperatures versus time-of-day. All temperature data was normalized relative to the bottom interior surface temperature of LNA1, i.e. there is one common baseline temperature for all the rest of normalization, thus, the LNA1 graph is nearly flat. LNA2 shows the differential temperature to LNA1.

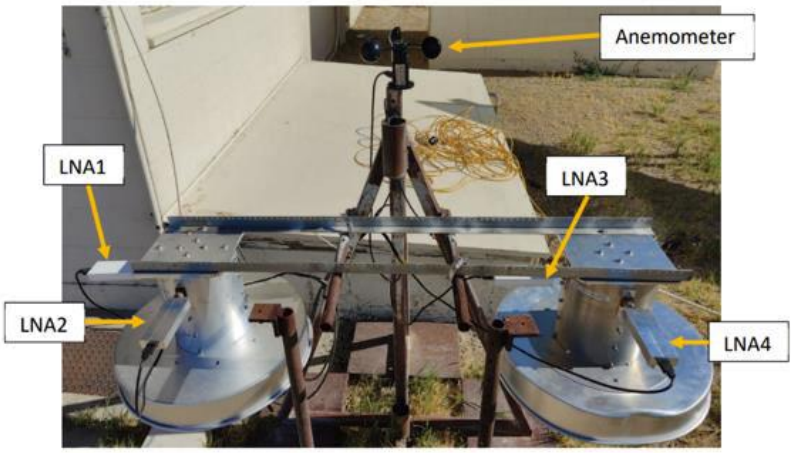
Based on the temperature sensor data shown in the plots, the following key temperature differentials were demonstrated near peak daytime temperatures:

- The temperatures of the top and the bottom interior surfaces of the SRI painted enclosure (LNA1) were up to 6 °C colder than the unpainted enclosure (LNA2)
- The interior air temperature of the enclosure was up to 6 °C colder in the SRI painted versus unpainted enclosure
- The temperature of the thermal load circuit board was up to 9 °C colder in the SRI painted versus unpainted enclosure

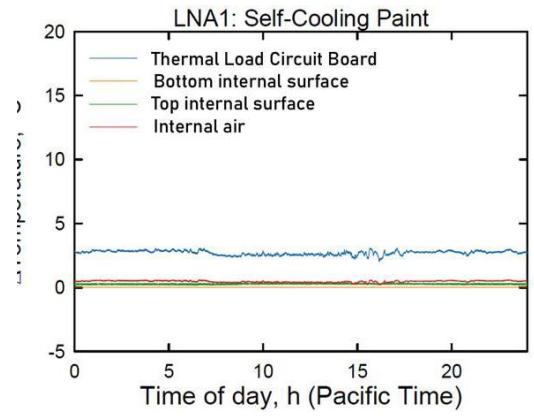
Prototype antenna

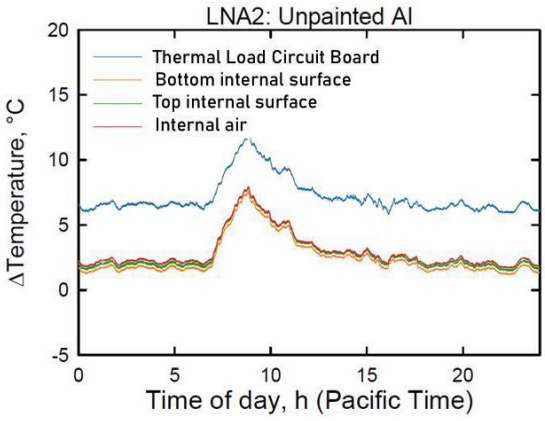
Test LNA

Reference LNA



Test setup. Cylindrical parts are the feeds and the LNAs are mounted by coaxial connectors to the feeds.





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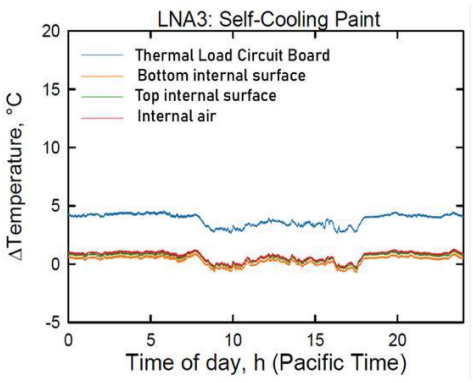
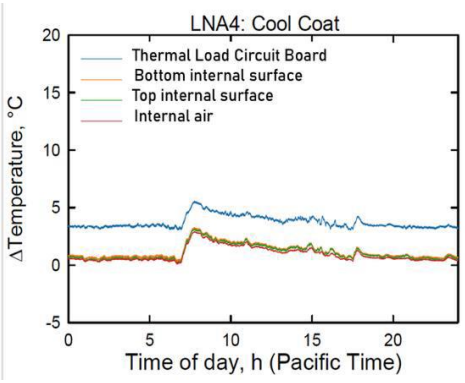
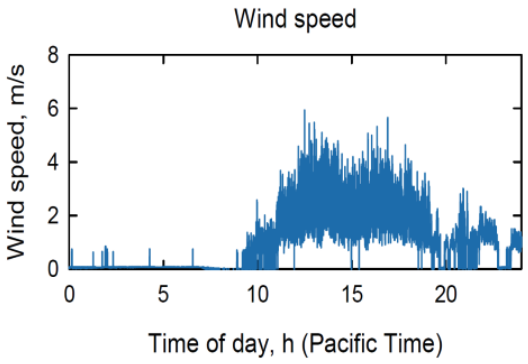
Below is a similar comparison of SRI Self-Cooling Paint coated block compared to a commercial cool paint. Caltech observed a maximum of 3°C - 5°C colder interior air temperatures inside SRI Self-Cooling Paint coated enclosures (LNA3) compared to the cool paint coated enclosure (LNA4). Note that LNA3 and LNA4 are normalized relative to the bottom interior surface temperature of LNA1.







CONCLUSION

Application of the SRI Radiative Cooling Paint resulted in a significant reduction in the internal temperature of LNA enclosures compared to an uncoated enclosure and even compared to a device coated with a commercial cool paint product. At peak solar exposure when cooling is the most critical, the SRI paint lowered the internal temperature of the interior circuit board as much as 9°C compared to an unpainted enclosure. When used with an operating LNA device, this reduction in temperature would lead to lower noise, higher sensitivity and increase lifespan of the device.

Achieving significant cooling of the sensitive LNA device without any consumption of electricity is expected to improve the performance of the radio telescope mounted LNA devices, as well as avoiding degradation due to elevated temperatures, while saving cooling cost and conventional resources like fans in the electronic blocks.

"The availability of the SRI Self-Cooling Paint presents new opportunities for improving the performance and lifetime of instrumentation deployed in the field."

CalTech Team

** Ambient temperature was measured by a thermistor placed next to the samples, hanging in the air. ** Based on internal tests o n an aluminum substrate*

About SRI

SRI is an independent nonprofit research institute, headquartered in Menlo Park, California., with a rich history of supporting government and industry. We create and deliver world-changing solutions for a safer, healthier, and more sustainable future. For more than 75 years, we have collaborated across technical and scientific disciplines to discover and develop groundbreaking products and technologies and bring innovations and ideas to the marketplace. Learn more at www.sri.com.

Contact

Contact SRI to inquire about partnership or licensing of the paint.

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