Designing Locally Cooled Radio Frequency Receiving Systems

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BACKGROUND AND INSTURMENT OBJECTIVES

In radio astronomy noise sources are classified in terms of thermal noise in units of temperature. Various sources of noise are present in radio astronomy observations. We can directly minimize the noise temperature of a radio frequency receiver with design choices. Radio signals are weak, so low noise amplifiers are used to increase the signal. These amplifiers are a large source of thermal noise – which can be minimized with localized cooling. Reducing the total noise of the system reduces the required observing time and elective dish area allowing for observation of pulsars and transients.

We seek to reduce the thermal noise within a radio frequency receiving system with the implementation of Thermoelectric Coolers (TEC) to provide local cooling.

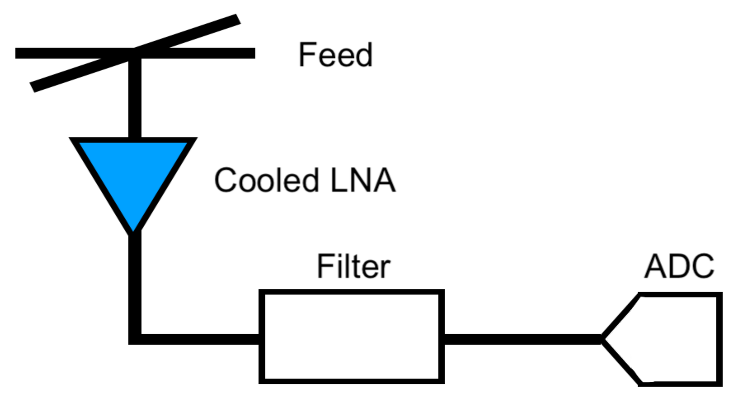

Fig. 1 Simplified radio frequency receiving system block diagram.

THERMAL MODELING

Finite Element Analysis (FEA) was used to predict the expected thermal behavior with implementation of the systems boundary conditions.

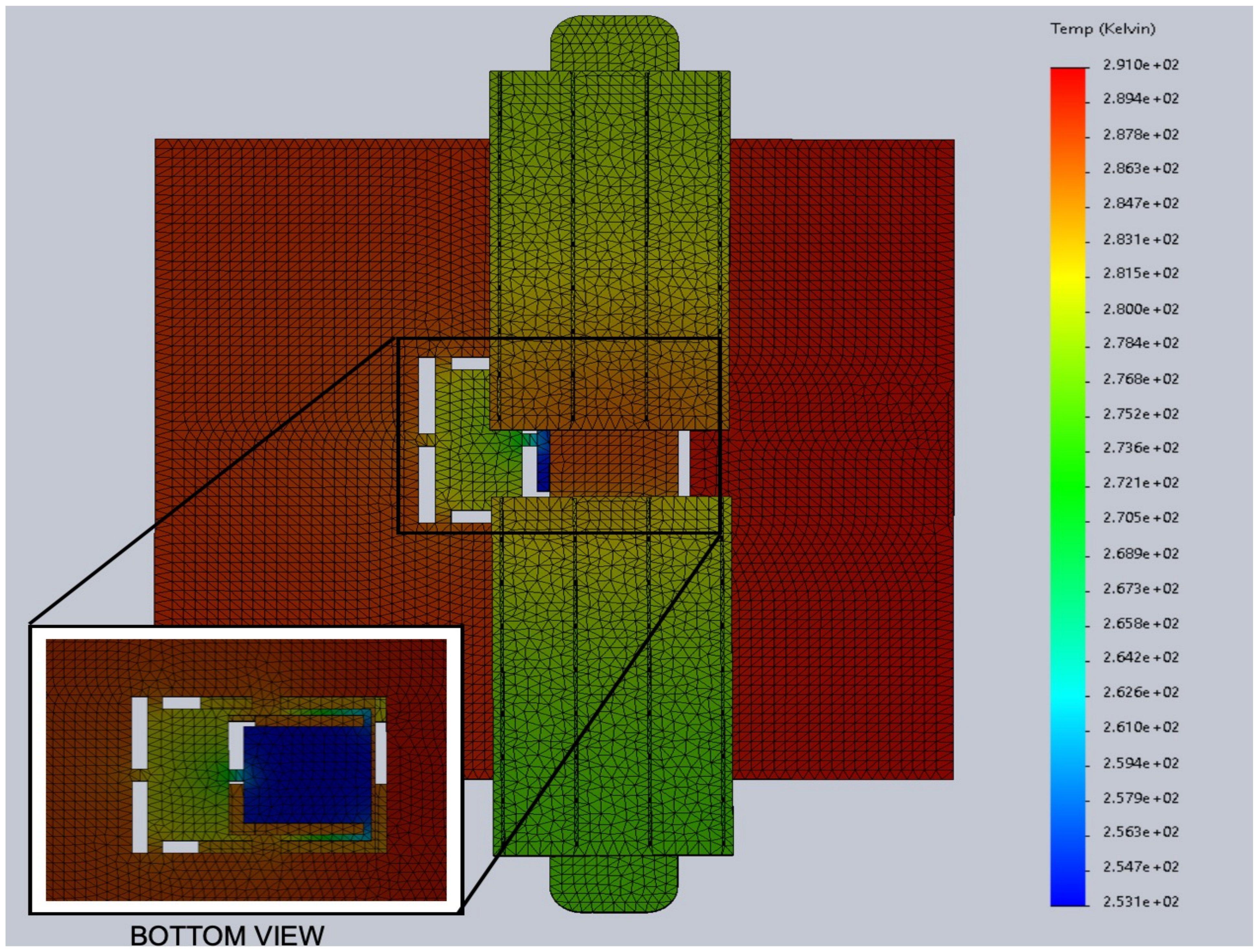

Fig. 2 FEA thermal modeling of simplified receiver system consisting of a LNA locally cooled with a multi-stage TEC equipped with passive thermal controls.

Thermal models predicted the ability to achieve a system temperature of ~253 K within the region of LNA housing on the PCB boards.

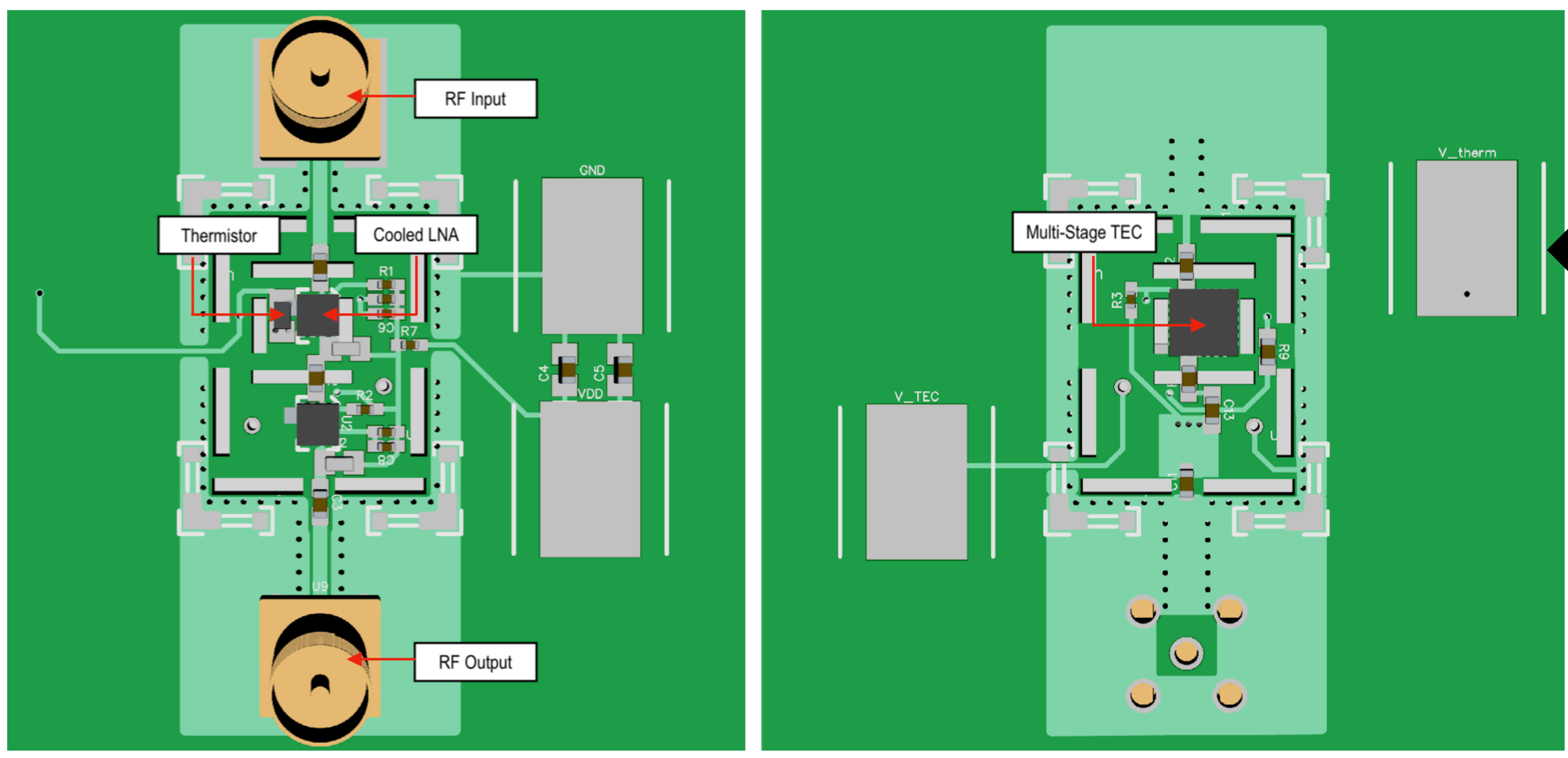

Fig. 5 Locally cooled Ultra-Low-Noise Amplifier (uLNA) Printed Circuit Boards (PCB) currently in production.

THERMAL TEST UNITS

Simplified thermal test units replicating the thermal model were constructed to optimize the cooling performance of the Multi-Stage Thermoelectric Cooler (TEC) and passive thermal control system.

Simplified test units were found to achieve a temperature of 256 K within the region of LNA housing on the PCB boards. This temperature is considerably below ambient (293 K) and is predicted to reduce thermal noise by ~20%.

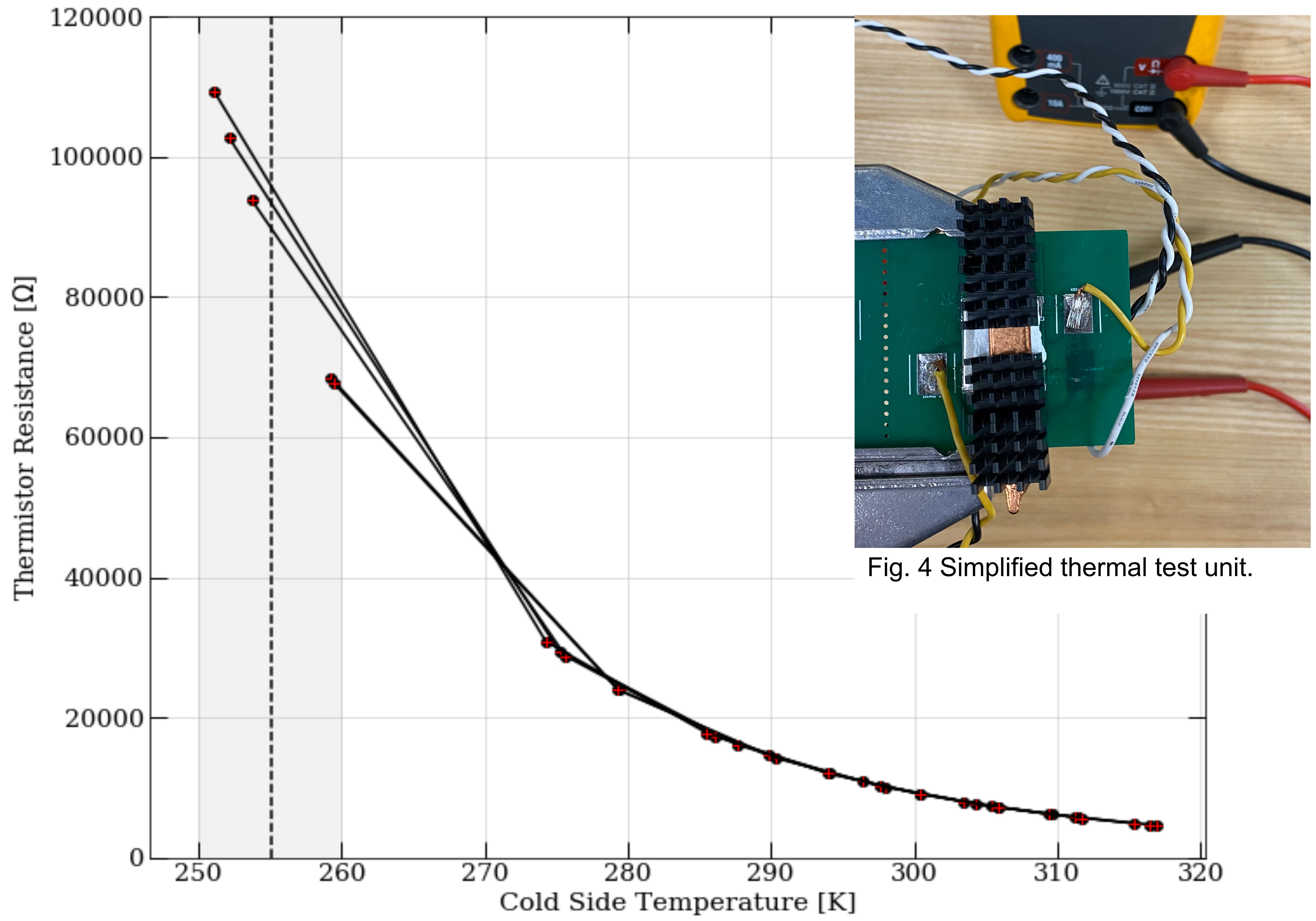

Fig. 4 Simplified thermal test unit.

Fig. 3 Thermistor resistance as a function of cold side temperature for 5 trials of laboratory tests utilized to determine optimal performance parameters of the Multi-Stage Thermoelectric Cooler. Maximizing the cold side temperature directly corresponds to a reduction in system noise temperature.

Refined thermal test units consisting of an active uLNA and operational circuit, multi-stage thermoelectric cooler, and thermistor circuit are currently in production.

FUTURE WORK

Complete manufacturing of PCBs and integrate into developed thermal test units. Following laboratory tests, **preform field tests** in the 300 – 1500 MHz radio band.

ACKNOWLEDGEMENTS

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