



Smart Water-Cooling System for Thermal Noise Reduction in Radio Telescopes: Design and MATLAB-Based Simulation

Taif Mahnashi, Joud Al-otaibi, Leen Alghamdi, Layla Alsanoni, Lina Alahmari, Raneem Alzuhair, Sireen Alqaznli, Leen Aljarbou

Department of Electrical Engineering, College of Engineering, Princess Nourah bint Abdulrahman University, P.O. Box 84428, Riyadh 11671, Saudi Arabia

Abstract

Thermal noise is a typical challenge with telescopes; this can represent a major contributor to the accuracy of observed signals, particularly in a hot environment like ours. With this project, we intend to implement an innovative water cooling system by integrating two Arduino to reduce thermal noise, which will ultimately provide better performance for the telescope. The first Arduino system uses temperature sensors to monitor temperature levels continuously, and the second Arduino automatically activates the water cooling system when the temperature reaches 38°C.

Many ways are taken to cut down on thermal noise in radio telescopes, such as passive cooling and material insulation, but they are often costly and complex. Our plan brings in an easy, cheap water-cooling fix with an Arduino to keep the heat steady.

Introduction / Background

Thermal noise is one of the dominating factors in telescope performance, especially in high-temperature environments. In regards to temperature, this increased temperature level increases the random motion of electrical charges within materials, resulting in electromagnetic noise. The existence of noise leads to signal degradation and consequently diminishes the precision and quality of collected data.

The power of thermal noise can be calculated using the formula:

$$P = kTB$$

P represents the noise power, k is Boltzmann's constant, T is the absolute temperature, and B is the bandwidth.

The effect of temperature change on the properties of the medium carrying the electromagnetic waves is represented by the temperature gradient:

$$\nabla T = \left(\frac{\partial T}{\partial x}, \frac{\partial T}{\partial y}, \frac{\partial T}{\partial z} \right)$$

Various methods have been used to reduce thermal noise in radio telescopes, such as passive cooling and material insulation, but they are often costly and complex. Our project introduces a simpler, low-cost water-cooling solution with Arduino-based temperature control to ensure stable thermal conditions.

System Model / Methodology

Our system consists of two Arduino Uno boards. The first reads the temperature using an LM35 sensor, and if it exceeds 38°C, it sends a signal to the second Arduino, controls the submersible water pump, and activates a DC motor to rotate the cooling unit, ensuring even heat distribution. LED indicators are used to display the system's status.

During the simulation phase, we were not able to actually detect radio signals. Due to the limited data and no access to the telescope, we used temperature readings derived from a simulated 7.2-meter telescope to assess the thermal response of the cooling system. We achieved different thermal conditions by simulating in MATLAB, which allowed successful testing of the cooling mechanism behavior. Thermal performance was validated through simulation, and future work will incorporate the system to detect real radio waves in real-world conditions.

Main components used:

- Two Arduino Uno Microcontrollers
- Temperature sensor LM35
- Submersible water pump
- DC motor
- LED indicators
- Water tank and pipes

. The system will be helpful for other applications as well, which require precise and continuous thermal control.

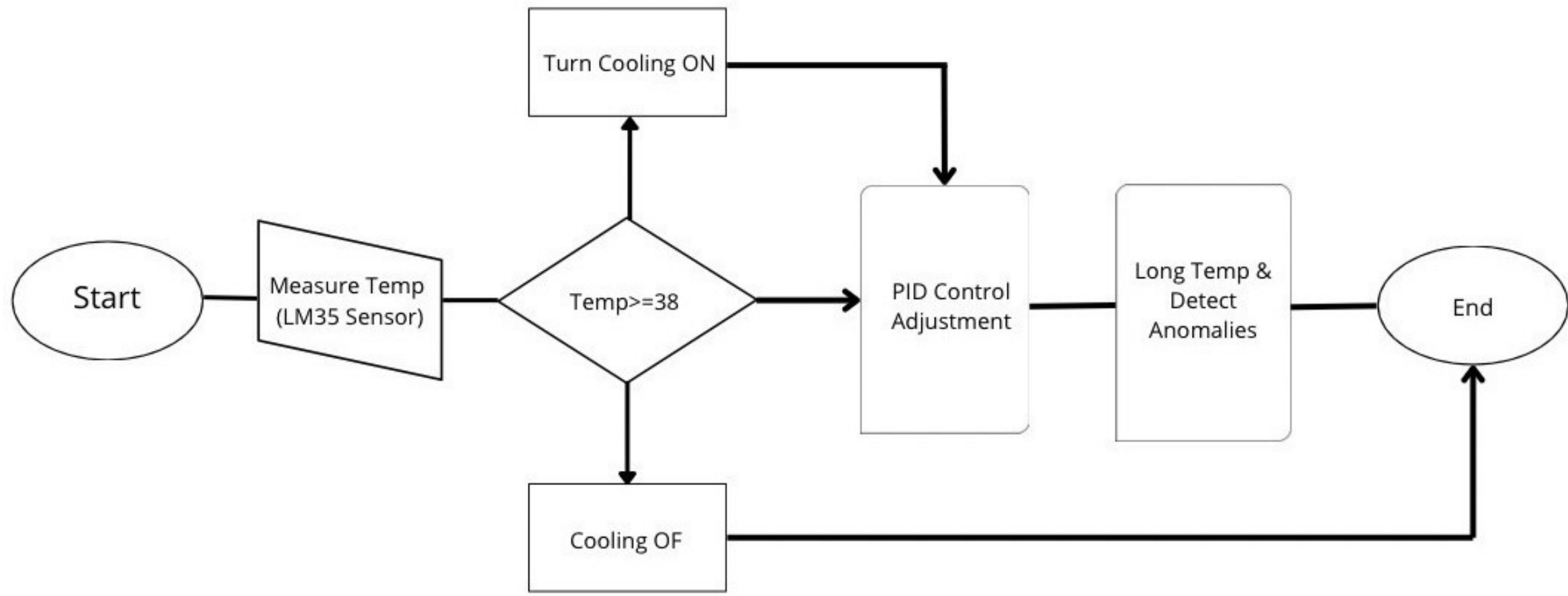


Figure 1. Flowchart of the Smart Cooling Control Process

Problem Statement/Proposed Solution

Thermal noise, or Johnson–Nyquist noise, causes random changes in voltages and current in RF systems and reduces the accuracy of received signals; it is also broadband, meaning it interferes at all frequencies at once. As the temperature in the radio-frequency system increases, the noise power subsequently increases in all frequencies, thus leading to challenges in recognizing the signals. In radio telescopes, thermal noise in frequency increases lower signal-to-noise ratios (SNR), reduces frequency resolution, and may cause data to be ignored. The better we understand thermal noise and its impact on RF receivers, the better we can improve RF receiver characteristics and the accuracy of space signal detection (Cadence, 2020).

To overcome this problem, we designed a simple and low-cost Arduino-based water-cooling system to reduce thermal noise. Initially, an LM35 temperature sensor monitors the surface temperature and sends data to Arduino A. The second Arduino B controls the cooling system. Once the sensor detects that the temperature has reached or exceeded 38°C with Arduino A then Arduino B will then start the cooling process gradually.

Description / Simulation / Results

the radio telescope). The system turns on cooling at 38°C and off at 35°C. This will minimize thermal noise and limit meaningless energy consumption. The reaction of a cooling system is based on a temperature regulation called (PID).

Results:

- Temperature Before and After Cooling: With cooling applied, the temperature remained consistently lower compared to the case without cooling, confirming that the system effectively stabilized the thermal environment.
- PID Output Over Time: We used a PID controller to manage the cooling process smoothly and efficiently. Instead of turning the cooling on or off, PID can adjust how strong the cooling should be based on how high the temperature was. This helped reduce sudden jumps and made the system more stable and realistic.

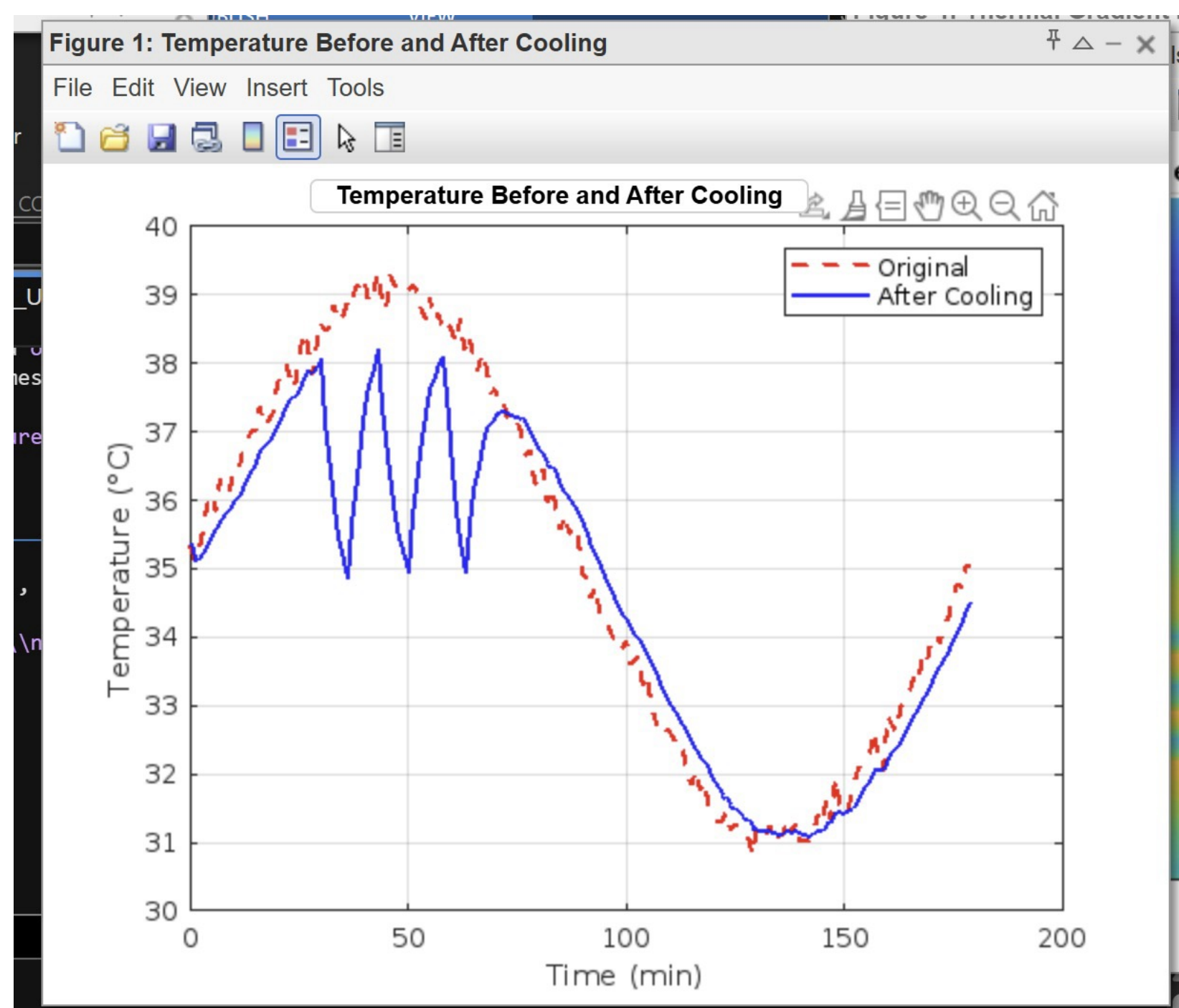


Figure 2. Temperature Response Before and After PID-Based Cooling

Conclusions

At the end, our team sought to address the thermal noise problem, a phenomenon that affects any electromagnetic reception system. The water-cooling system we developed not only represents a practical solution to the thermal noise problem but also represents a step toward improving the accuracy and efficiency of the astronomical medium. By integrating Arduino technology with the telescope, we were able to present a prototype that can be developed in the future. We hope this project will be the beginning of broader research and applications in this field.

Contact:

Joud Al-otaibi
Email:mtjood@gmail.com

References:

