SuperDARN HF Radar Lab at VT: Transmitter Monitoring

Designed by: Tanner Beamer, William Betz, Corwin Carpenter, Wesley Flynn, Dagmawi Theodros
Sponsor: Kevin Sterne, Virginia Tech
Professor: Dr. Adams and Dr. Connors, Virginia Tech

What is SuperDARN?

SuperDARN is an acronym for the Super Dual Auroral Radar Network. The network consists of over 30 low-power radar arrays that observe the Earth's atmosphere for plasma motion in the ionosphere; providing key insight into Earth's space environment. This is accomplished by sending busts of pulses through a transmitter and connected antenna, then receiving the returned signal and interpreting it.

While our project focuses on the site in Blackstone, VA, SuperDARN is an international collaboration between 19 universities. Virginia Tech, Dartmouth College, Penn State University, and the John's Hopkins University Applied Physics Laboratory (APL) represents the U.S. component of the network, which is funded by the National Science Foundation (NSF).

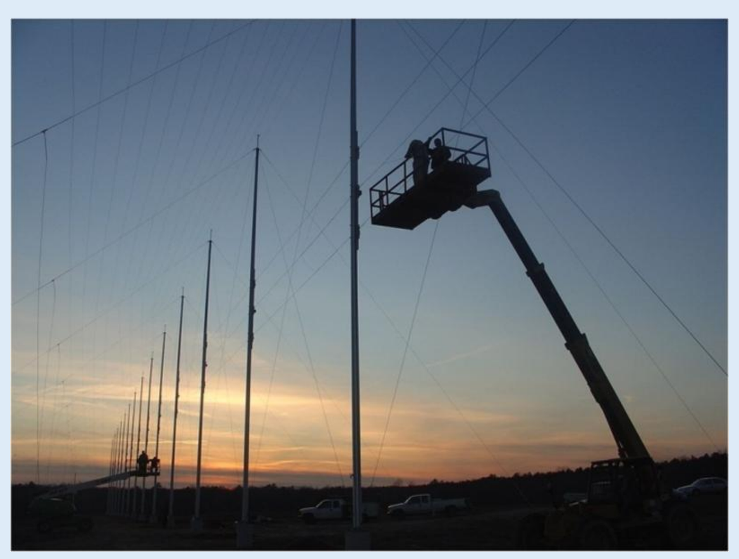

Figure 1: View of the SuperDARN antenna array at Blackstone, VA. Source: http://vt.superdarn.org/gallery

Figure 2: Image of the transmitters and computer at the Blackstone, VA site. Source: http://vt.superdarn.org/gallery

The Problem and How Can We Help?

Problem

- SuperDARN sites are located in remote areas
- The health of the 18 transmitters onsite is unknown without a technician traveling to the site
- This uncertainty and inaccessibility makes maintenance time consuming and costly

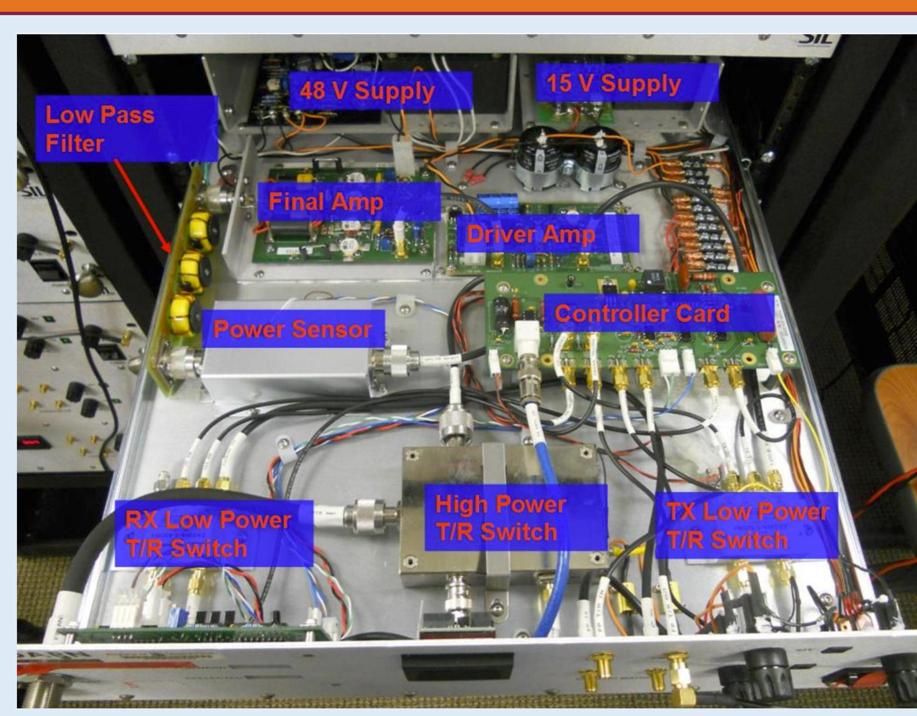

Figure 3: Labeled image of a transmitter at the Blackstone, VA site

Project Objectives

- Create a cost-effective system that monitors SuperDARN transmitters at the Blackstone site
- System must measure status voltages and temperature from all 18 transmitters on-site
- System must use the existing site computer to make measurements remotely accessible to technicians

System Design

System Overview

Our system consists of 18 Sensor Units, one inside each transmitter, and a Sensor Unit connected to the site computer. The Sensor Units communicate to the Sensor Hub using Wi-Fi, and the Sensor Hub is connected to the computer via USB. Below is an example of one Sensor Unit and Sensor Hub connected to the transmitter system.

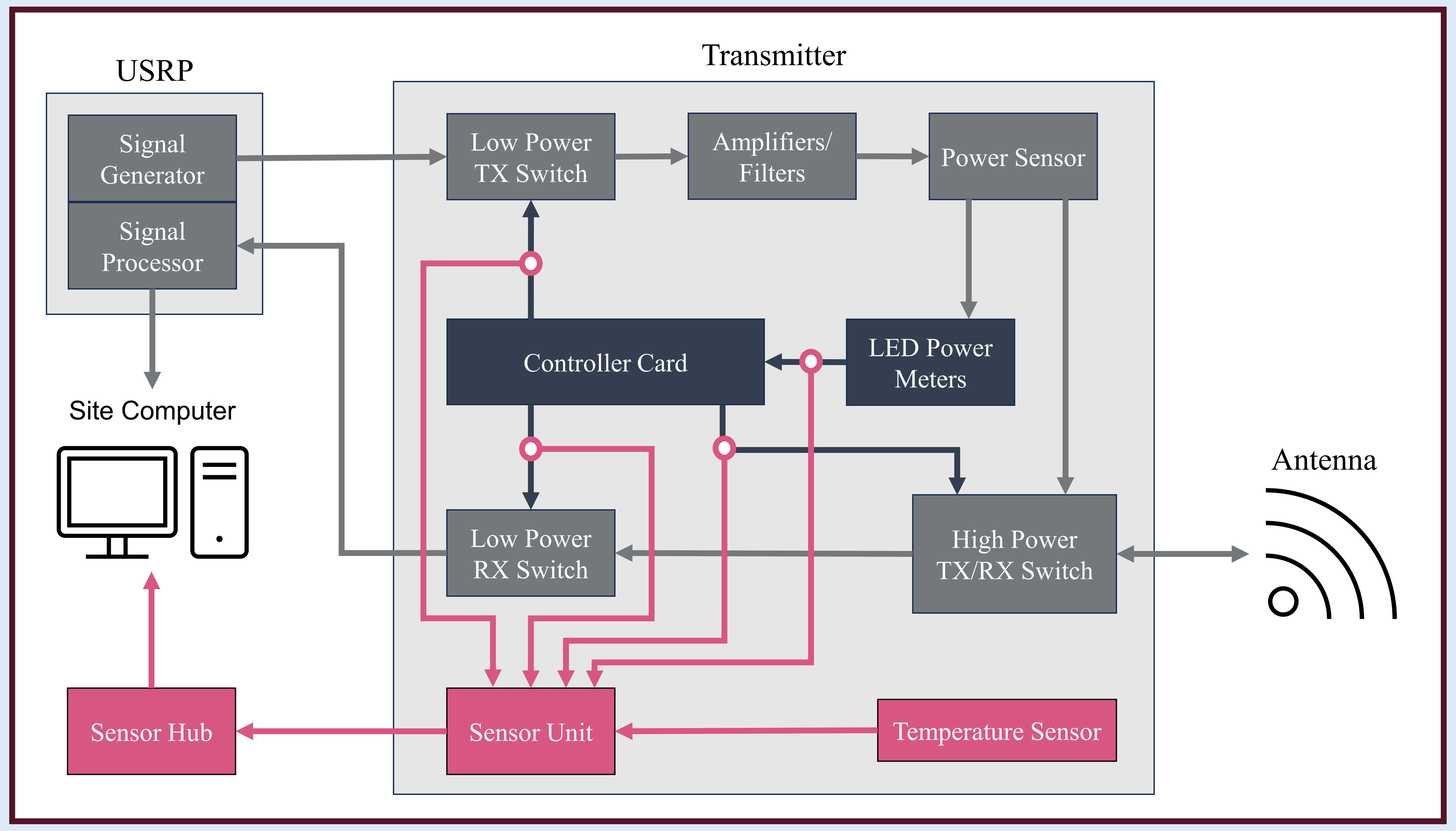

Figure 5: A flow chart of the implemented measurement system

Sensor Units

Each unit, driven by an ESP32 microcontroller, reads status voltages from the transmitter in which it is installed. These voltages are carried by jumper wires between the signal path components and the transmitter's controller card:

- High SWR Flag
- Low Power RX/TX Switch Pulses
- 400V High Power Switch Supply

Each unit also contains a temperature sensor for in-case thermal readings.

After assembly, all one must do to install a Sensor Unit is:

- Disconnect the jumper wires from the controller card
- Connect the jumper wires to the Sensor Unit
- Use additional jumper wires to connect the Sensor Unit to the controller card, allowing for signal passthrough
- Attach the Sensor Unit's power leads to the existing 15V supply terminals

Sensor Hub

- The central system to the entire sensor system
- Consists of single ESP32 running a Real Time Operating System (RTOS)
- Connected to site computer via USB

Software

- The Sensor Hub uses FreeRTOS to handle connecting to and reading the data send from the Sensor Units every 500ms.
- The Sensor Units themselves also employ FreeRTOS to handle the simultaneous reading of status signals.
- The collected data is sent from the Sensor Hub to the site computer to be stored in a CSV file.

Measurement Data Handling

Sensor Unit
- Analog Voltages
- Boolean Flags
- Ambient Temperature

WI-FI ↓

Sensor Hub
- Verify MAC address of Sensor Units
- Collect readings from all Sensor Units
- Append readings to UART stream

USB ↓

Site Computer (Linux x86)
- Verify serial readings
- Adds timestamp
- Save to CSV log file

Outcome

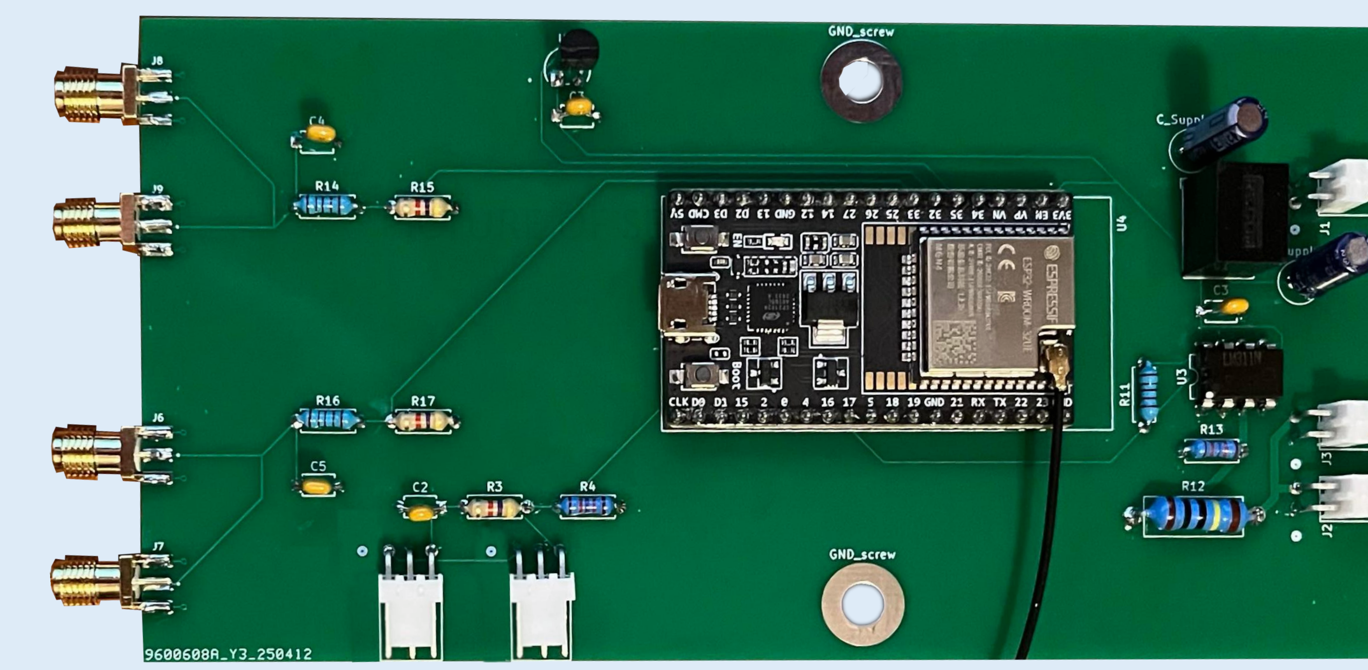

Figure 5: A picture of the PCB design of the Sensor Unit

Cost

- The total cost of components for an 18-transmitter radar site is **$496.63**, equivalent to **$27.59 per transmitter.**
- This cost excludes the price of external wires and cables, but includes the necessary connectors and crimping materials.

Fault detection

- The following table of scenarios give examples of fault events and how they are detected by the sensor units. The flag lets the user know if the transmitter or antenna faulted.

Cause of Failure	Response	Result
Lightning strikes the antenna causing it to fail	high reflected power is detected by the power sensor and the transmitter shuts off	The Sensor Unit reports the opening of the low power switches and the high SWR flag
A transistor fails in the High Power TX/RX Switch	The 400V high-power switch supply drops to a low voltage	The Sensor Unit detects the voltage drop and changes the value sent to the log accordingly
The air conditioning system for the transmitter room fails	The transmitter begins to heat up	The Sensor Unit measures the increase in temperature and records it to the log

Future Steps

Compactness

The PCB (Figure 5) has a lot of unused space. Given more development, a more compact PCB layout could be developed, saving on space.

Signal Measurement

We only learned the true nature of the control signals after gaining access to a transmitter about a month before the end of the project. With the knowledge gathered from hands-on testing, we realized more optimized methods of status reporting can be deployed. For example, we learned that the control signals for the low power TX and RX switches are the same. This means that one of the signals currently measured is redundant and can be ignored.

We also determined many of the control signals behave more like pulses, as the transmitter restarts itself within milliseconds of detecting a fault. Circuit-based sample and hold techniques could be used instead of software-based ones, allowing for more efficient operation of the ESP32.