University of Michigan
Space Weather Sensor Package

Masterson, T., Moldwin, M.B., Ojeda, L., Vata, J., Fertig, I., Hofmann, A., Tsang, B., Jupudy, A., et. al.
University of Michigan

Abstract

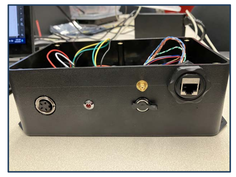
Ground magnetometer and dual frequency GPS systems are used to measure space weather effects observed in geomagnetic disturbances and variations in Total Electron Content (TEC). However, such systems are usually cost-prohibitive, susceptible to noise from human infrastructure, and difficult to deploy and maintain. Our team has been working on a low-cost space weather sensor package that can be easily deployed and requires low maintenance while having good magnetic and TEC data accuracy. The system has multiple options with respect to power (e.g., AC powered or solar panel and battery system), communication (Cat5 internet, Wi-Fi, Cellular or satellite modem), and sensors (use of network protocol time, single frequency GPS time stamping, or dual frequency GPS for both time and TEC). This presentation describes the low-cost magnetometer sensor package, the simple user interfaces, and design of the electrical and structural components for ease of manufacturing. We have developed a prototype for a system that is much cheaper and easier to mass-produce and install than current commercial systems, and real-world testing has shown that these systems function reliably.

Introduction

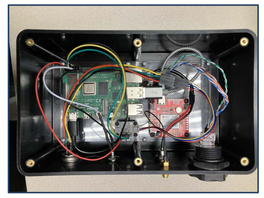
This project aims to reduce the cost and complexity of manufacturing and installing space weather sensor systems. Existing systems are often cost-prohibitive–a system produced by Miles FG costs ~$25K.[1] A low-cost system should require minimal time and tools for set up and be easy to interface with while retaining the quality of the data.

The prototype for the space weather sensor package fits in a small form factor and consists of a relatively small number of parts.

The sensor peripheral enclosure with the top removed–the sensors inside are a PNI rm3100 magnetometer and a TMP461 temperature sensor. The enclosure is NEMA 4X waterproof rated, and the shielded cable can be extended up to 100ft.



The device enclosure with the top case removed. Designed to be placed indoors, it has 4 jacks: sensor peripheral, DC power, GPS antenna coax, and Ethernet. A red indicator LED flashes when the device is on and logging data.



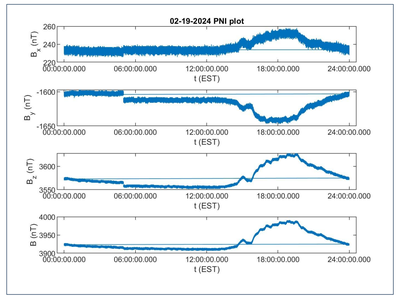
Shown above are 3 main electronic components: the GPS board, I2C active terminator, and Raspberry Pi computer. All of them are mounted on standoffs to an acrylic base plate manufactured in-house.

Using two types of screwdriver bits and an adjustable wrench, the top of each enclosure can be unscrewed and any component can be replaced.

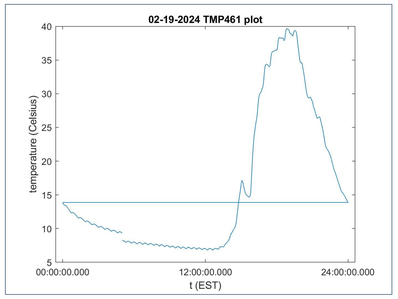
Design

- Uses low-cost PNI RM3100 magnetometer and TMP461 temp sensors.
- Components manufactured in-house are produced in bulk to reduce manufacturing costs.
- Runs off 5VDC from an AC adapter.
- Insulating ABS plastic enclosure eliminates the risk of hot-to-ground faults, allowing use of a 2-prong plug.
- Sensor peripheral is in a waterproof enclosure, allowing it to be routed outside and placed in the ground for thermal insulation.
- High-accuracy GPS tag with waterproof antenna.
- I2C active terminator and shielded cable allow the flexibility of routing the peripherals outdoors away from noise sources.
- Connects through either Wi-Fi or Ethernet and uploads data to Dropbox.

Data and Testing



Testing has shown that the magnetometers have low noise levels (+/-5nT) when installed correctly. The plots above shows both the magnitude (top) and the x, y, and z components of the magnetic flux density.



Temperature can be graphed as well, which is useful when calibrating the magnetometer data for temperature variations. As shown by the plot on the left, variations in temperature can cause significant magnetometer variations.

Power consumption averages around 3-4W when collecting data and 5-6W when transmitting over Wi-Fi or Ethernet, based on testing using an ammeter with a DC power supply.

Cost Breakdown

Component	**Cost (USD)**
Parts	210.00
Optional dual freq GPS rec + antenna	350.00
Assembly Labor	30.00
Total	$240-$590

This represents an **96.7%-99%** reduction in cost.

Next Steps

This sensor package has proven cost-effective, reliable, and easy to manufacture and service. It's essentially plug-and-play, simply needing a standard 120V outlet for power and two cable entrances for the peripherals. Later stages of the project will further improve the existing system's manufacturability and reliability, and create a product family of additional systems with different power sources, communication protocols, and sensor options.

Improvements to the Existing System

- Reduce the cost of connectors (currently ~25% of cost).
- Reduce the number of solder joints and crimps.
- Adding mounts to the PNI board for stability and vibration resistance.
- Finding suitable direct burial cable for the sensors.
- Use a lower-cost GPS chip.
- Quad mag sensor with 4 PNI chips that greatly reduces noise.[2]

Solar Powered Outdoor Sensor Package

- Deployed outdoors and runs on solar power & a SLA battery.
- Can be placed in remote areas away from noise sources.
- Withstands ranges of temperatures and weather conditions.
- Communicates through cell modem, Wi-Fi hotspot, and Ethernet cable.
- Uses low-power microcontroller instead of RPi.

Low Power Sensor Package

- Has lower power consumption for battery-powered systems.
- Microcontroller specifically optimized for the sensors from the package.
- Can pull data from Bluetooth or SD card, simplifying interface and eliminating network setup.

References

[1]Leonardo H. Regoli, Mark B. Moldwin, et. al., Investigation of a low-cost magneto-inductive magnetometer for space science applications, 2018.
[2]Brady P. Strabel, Leonardo H. Regoli, et. al., Quad-Mag board for CubeSat applications. Copernicus, 2022.

Acknowledgements

We would like to thank Prof. Moldwin, Lauro Ojeda, and everyone on the team for making this possible, and CWRU and HamSCI for hosting.

tsmaster@umich.edu