Plant Doctor: Batteryless Backscatter Radio Sensors for Plants and Agriculture

RUTGERS
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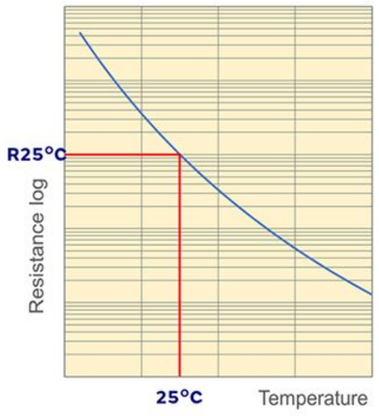
Abstract

Leaf surface temperature reveals a plant's physiological state, influencing photosynthesis, respiration, and water flow. It also indicates plant communication, as VOCs (volatile organic compounds) released from damage or insect attacks cause nearby plants to respond, specifically through temperature changes.

Overview

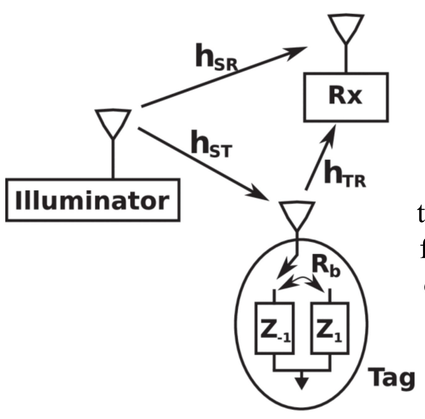
Stress is measured through leaf temperature using NTC thermistors following a curve defined by their B-value. Backscatter radio sensors, which reflect and encode ambient radio waves, offer a low-cost, energy-efficient way to transmit this data. This project aims to build a multi-sensor network to monitor plant temperature and communicate using backscatter.

Figure 1: Negative Temperature Coeffcient Thermistor Graph [4]



Backscatter

Figure 2: Diagram of backscatter methodology [2]



Illuminator is radio signal generator, tag is controlled by a square wave that switches the load. The frequency of the square wave adds that frequency and harmonics of it to the radio wave in the frequency domain

Temperature Apparatus

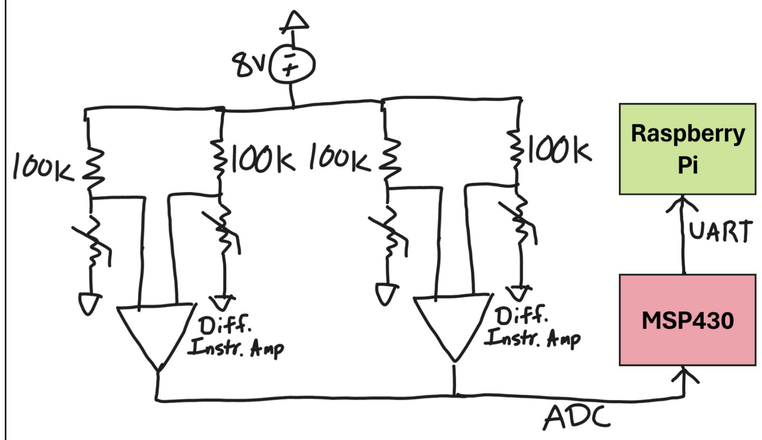


Figure 3: Diagram of setup
Wheatstone bridges made to take differential temperature between each pair of thermistors. Sent to ADC converter on MSP430 and then to python script on Raspberry Pi.

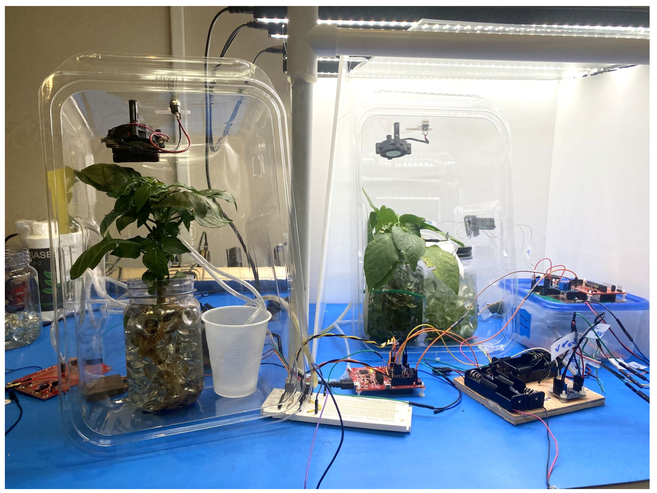


Figure 4: Experimental Setup
Two Plant Setup each with a thermistor touching the plant and a control paper with a water pump and lights setup for stress, plants are not touching in any way

References

[1] Batteryless Backscatter Sensor Networks-Part II: Lessons from Scalable Deployment | IEEE Journals & Magazine | IEEE Xplore, ieeexplore.ieee.org/document/10018185/;jsessionid=QynYUbYvrmUSrgzYMtOU0csqjr0PqJ1EGG5VoMmdXUJ8PGDNVWeO!2024649181. Accessed 29 July 2025.
[2] Batteryless Backscatter Sensor Networks—Part I, ieeexplore.ieee.org/document/10018209. Accessed 29 July 2025.
[3] Switching Frequency Techniques for Universal Ambient Backscatter Networking | IEEE Journals & Magazine | IEEE Xplore, ieeexplore.ieee.org/document/8474355/. Accessed 29 July 2025.
[4] Murata Manufacturing Co., Ltd. *Basic Characteristics: Basic Knowledge of NTC Thermistor*. Murata, https://www.murata.com/en-us/products/thermistor/ntc/overview/basic. Accessed 29 July 2025.

Results

Figure 5: Photos from Spectrum Analyzer
Demonstration of Frequency Shift Keying (FSK)

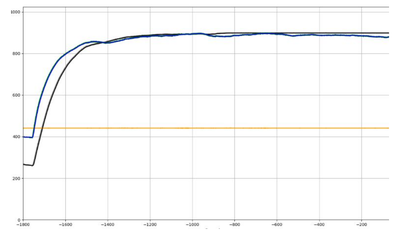


Figure 6: 2 Leaves 1 Plant **X-Axis:** Time (s) **Y-axis:** ADC Counts

Leaf 1 (black) behaved like Leaf 2 (blue) under water deprivation and light exposure, both averaging 880 ADC counts, a 0.88°C rise from room temperature, suggesting a hypothesized equilibrium state.

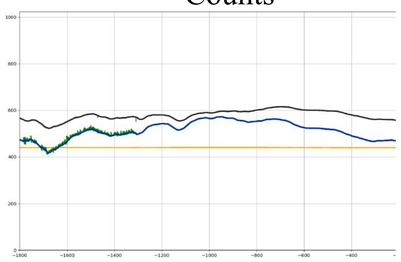


Figure 7: 2 Different Plants
X-Axis: Time (s) **Y-axis:** ADC Counts

Plant 1 (black) is being deprived of water. Plant 2 (blue) reacts in a similar fashion while experiencing no external stress, suggesting it is reacting to the stress Plant 1 is experiencing

Future Work

- Make backscatter receiver to decode modulated information
- Refine thermistor setup and plant chamber
- Run additional multi-plant experiments

Acknowledgements

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