Electromagnetic Soil Moisture Sensor (ESMS)

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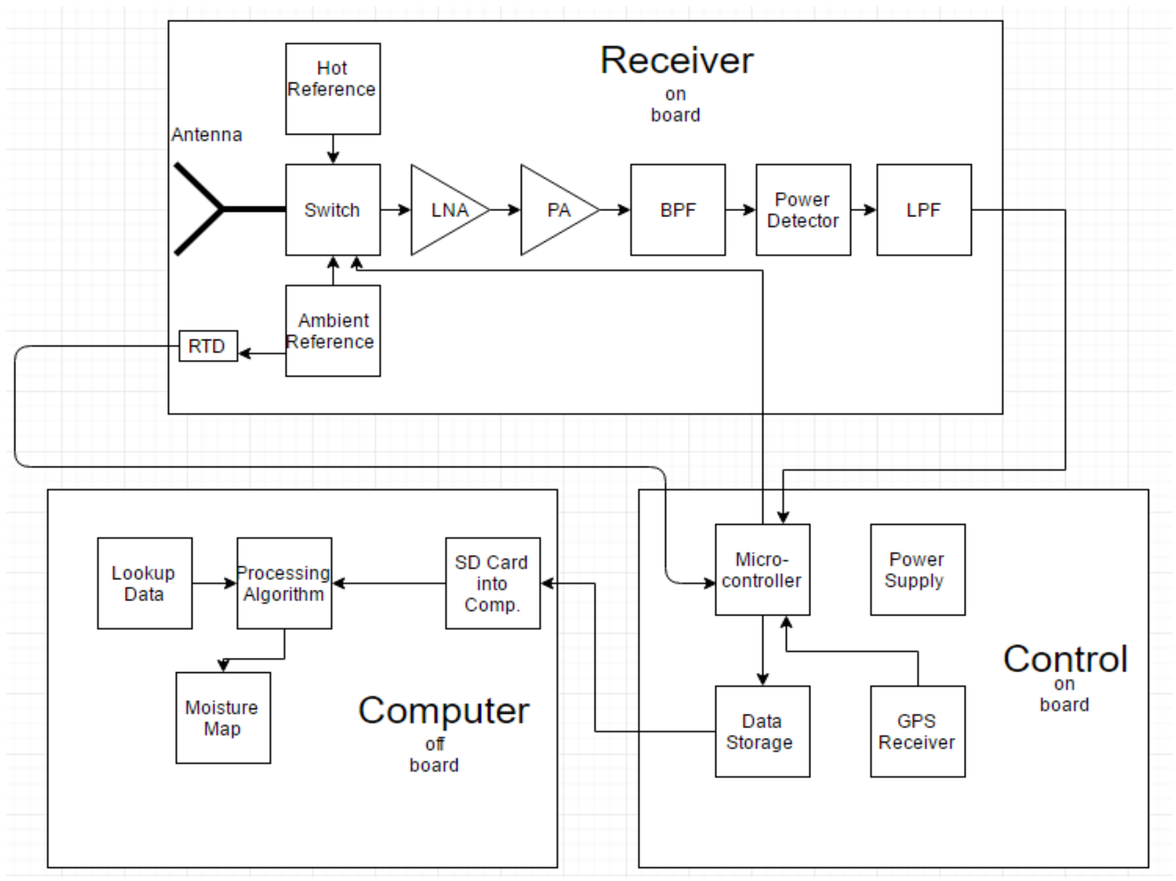
Abstract

Electromagnetic Soil Moisture Sensor is an electromagnetic system that allows users to map moisture levels over a small area of soil. It detects the brightness temperature of measured soil using an antenna. Soil with higher moisture contents will have lower brightness temperatures, so this brightness temperature data can be used to map soil moisture. Soil moisture is a key variable in controlling water and heat energy between the land surface and the atmosphere. Therefore, soil moisture plays an important role in the development of weather patterns. The signal captured is then fed into a Radio Frequency (RF) receiver, where it's amplified and filtered. The filtered data is then saved on a micro SD card. The data in the SD card is processed in a computer to produce a position vs. brightness temperature map of the landscape.

Applications

ESMS could be used by farmers trying to map the moisture on their land in order to optimize or design their irrigation systems. It could also be a useful tool to speed up the process of wetland delineation, which is required before construction projects may begin.

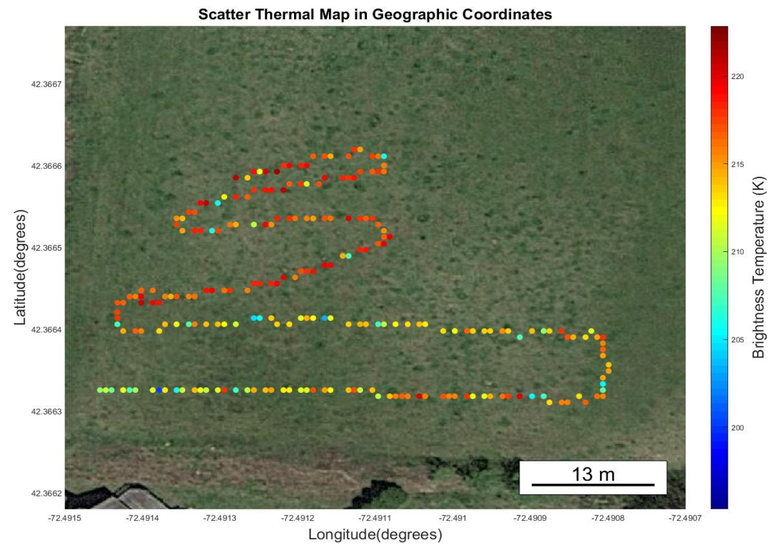
Block Diagram



System Overview

ESMS consists of three major subsystems: the RF receiver, system control, and off board data processing. Two reference sources, used to account for gain fluctuations, are alternately fed to the receiver by the system control. The receiver output for each source is saved on an SD card, along with the GPS coordinates, ambient temperature, and timing data. After operation, the text file from the SD card is passed to a data processing algorithm in MATLAB, which produces the thermal map.

Results



The top plot shows the tracked path we took through an open field in South Amherst. The bottom plot shows an interpolated brightness temperature map created using data from the scatter plot.

Device Specifications

Spec	Goal	Actual
Weight	< 5kg	3.63 kg
Radiometric Sensitivity	< 5 K	0.81 K
Operation time	> 30 minutes	2 Hours
Cost	< $500	$714.72

Acknowledgements

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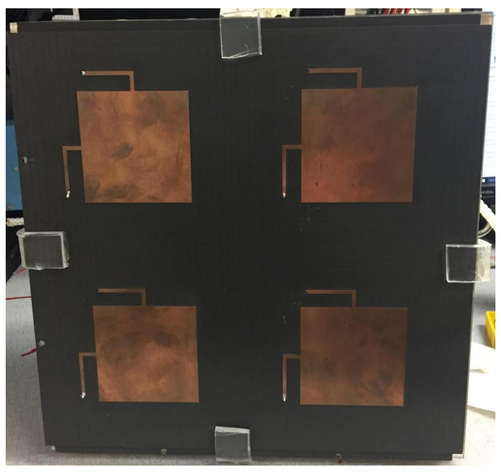
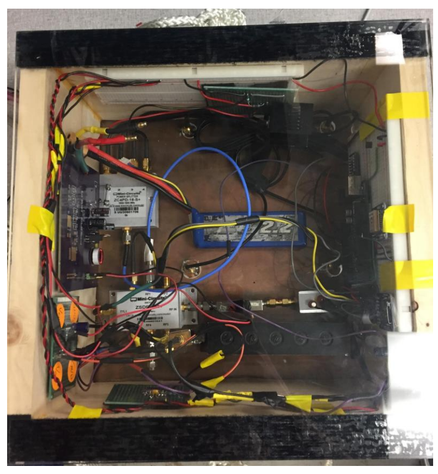
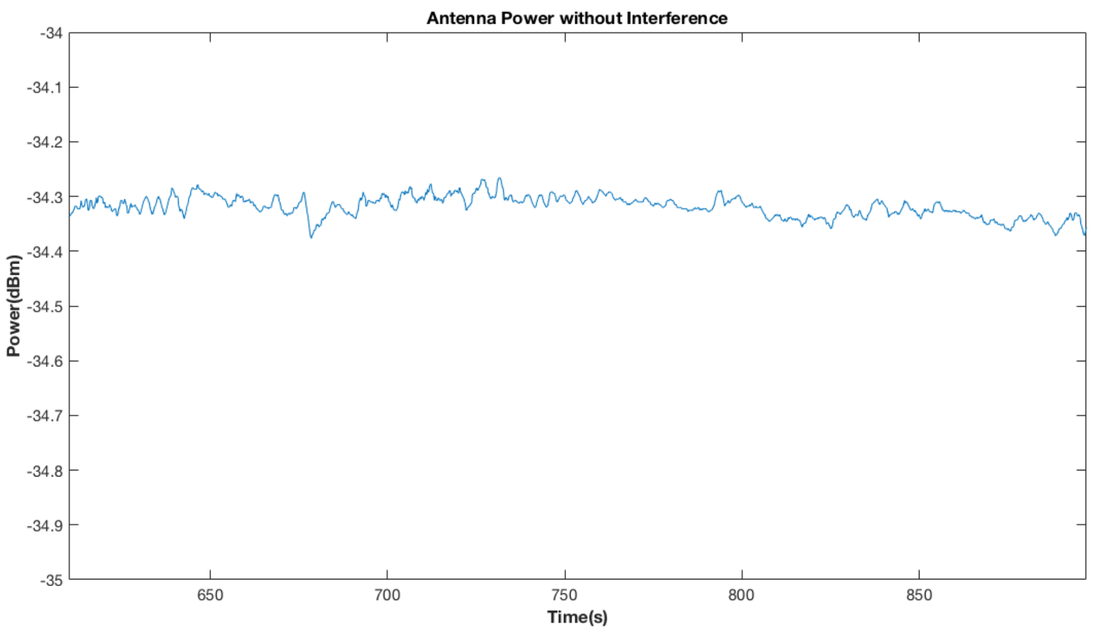
Casing

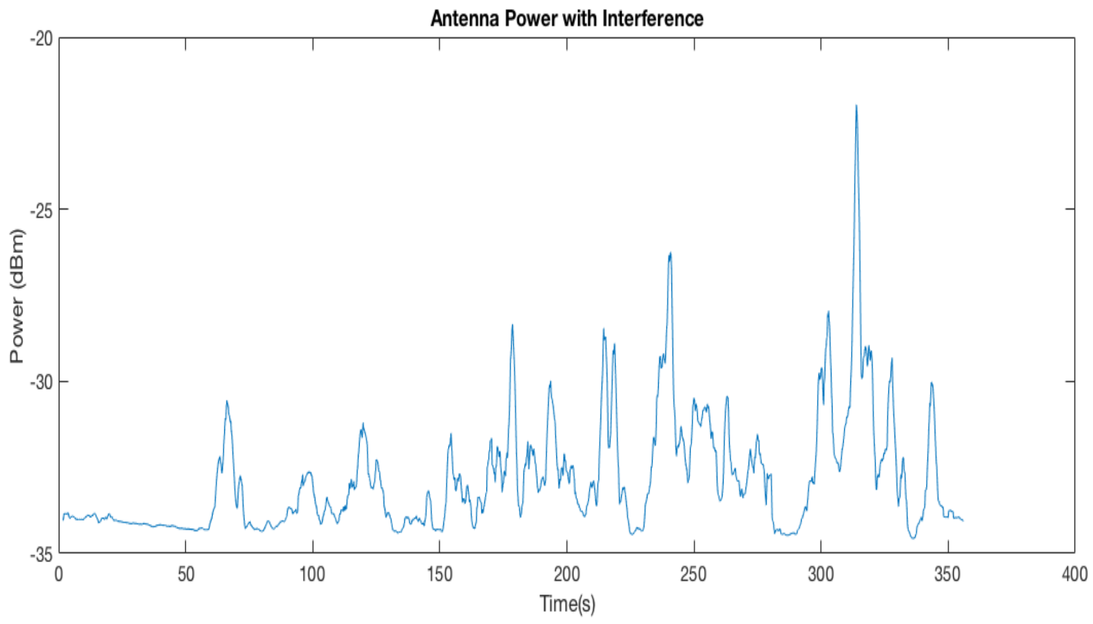




The RF components, system control circuitry, and power supply are cased in a 28 x 28 x 11 cm wooden box with a removable plexiglass top. The antenna lies underneath the box, pointing at the ground. The antenna must be suspended at least 3 m above the ground to take measurements from its far field.

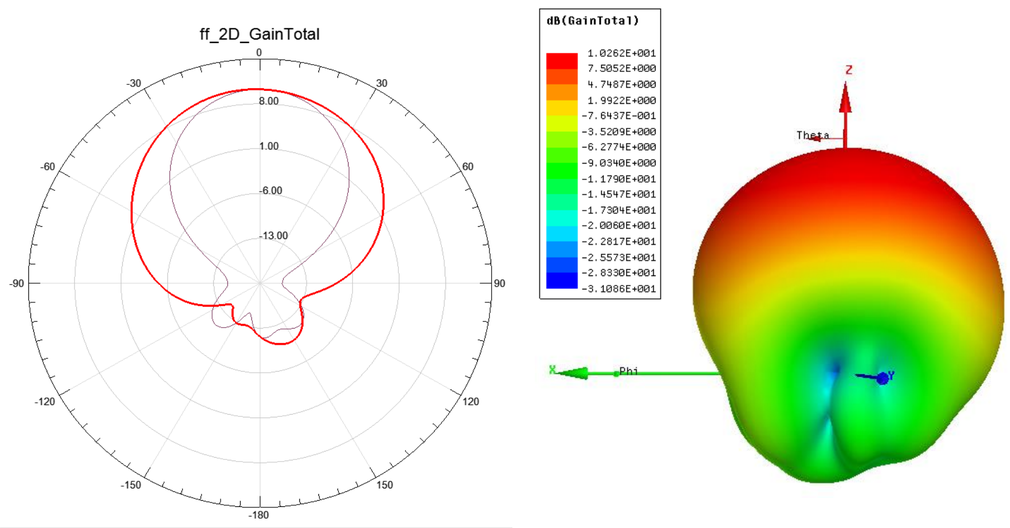
Interference





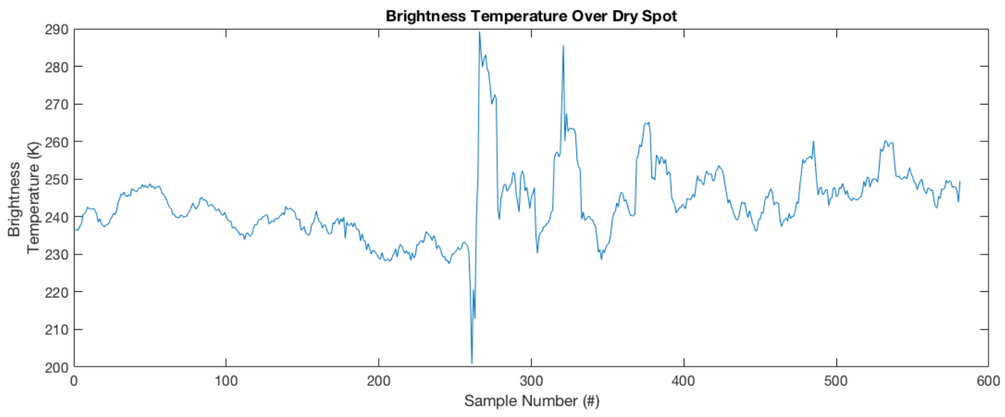
RF interference is detrimental to the operation of our project. The above two plots compare the power received by our antenna in an open field (top), and in the middle of the engineering quad and UMass (bottom). As the plots show, the measured antenna power varies by less than 0.2dBm in the open field, where it experiences little to no RF interference. In the engineering quad, the measured power varies rapidly, by a maximum amount of 12.5dBm. Since measured brightness temperature is directly connected to the power the antenna receives, the RF interference present in the engineering quad takes away from the quality of the data that can be taken there. Our most reliable data has been collected in the open field, where RF interference is not a problem.

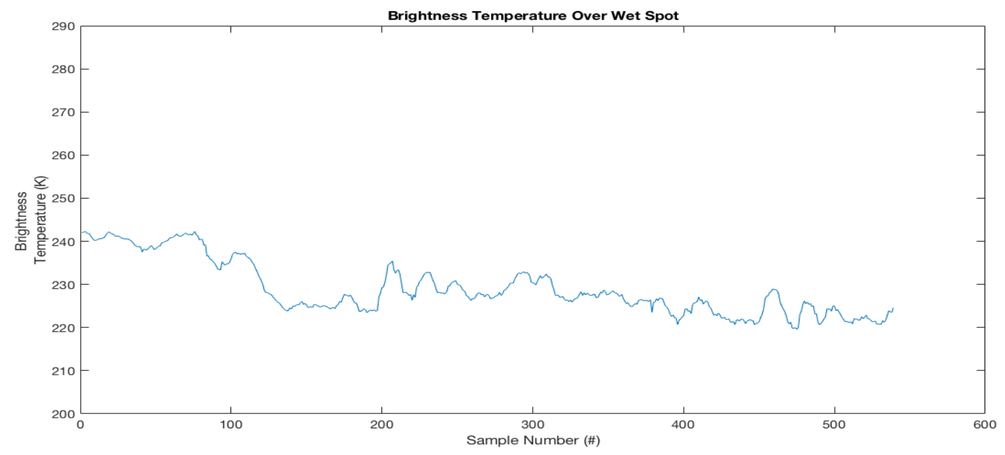
Antenna Radiation Pattern



2-dimensional (left) and 3-dimensional (right) antenna radiation patterns

Dry vs. Wet Soil





To test how our system would detect differences in measured brightness temperature between soils of different moistures, we suspended the system in one location over wet and dry soil for two minutes each. The top plot shows measured temperature of the dry spot vs. time, and the bottom plot shows the same for wet soil. The measured mean brightness temperature was 243.5K for the dry soil, and 228.9K for the wet soil.

Cost

Part	Development	Production
PCB	$28.67	$22.34
Antenna	$0	$67.99
Low-Noise Amplifier	$129.95	$102.95
Power Amplifier	$105.95	$102.95
Band Pass Filter	$39.95	$38.45
Power Detector	$89.95	$70.45
Power Combiner	$102.95	$89.95
Arduino Microcontroller	$37.95	$32.65
GPS Receiver	$39.95	$31.96
15-bit ADC	$14.95	$11.96
Noise Diode	$0	$3
RF Switch	$116.95	$106.95
MicroSD Breakout	$7.50	$6.00
Total	$714.72	$687.60