Title of Investigation:

Handheld Microwave Radiometer for Education and Outreach

Principal Investigator:

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Co-Investigators:

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Initiation Year:

FY 2004

FY 2004 Authorized Funding:

$60,000

Actual or Expected Expenditure of FY 2004 Funding:

$60,000

Status of Investigation at End of FY 2004:

Transitioned: minimum success criteria met in FY 2004. Work will continue under the education portion of Piepmeier's Earth Science New Investigator Project, in collaboration with CAMRA at Morgan State University.

Purpose of Investigation:

Passive microwave remote sensing is perhaps the most important, yet least understood technique used in Earth remote sensing. The goal of this investigation is to build a low-cost, 1.413-GHz handheld microwave radiometer for use in educating students about microwave radiometry. (The radiometer is a device that detects radio waves 21 centimeters in length. Radiometry is the art and practice of measuring microwave radiation for learning the temperature of an object. In our case, that temperature can tell you about the amount of water present in the soil.) One such educational outlet is the GLOBE program, a NASA-sponsored program aiming at promoting environmental awareness among young students worldwide. The handheld radiometer will contribute to GLOBE's soil moisture test protocol. In addition, the instrument could serve as a student-operated validation tool for two pending NASA missions—Hydros and Aquarius. The microwave radiometer we are investigating is a conventional Dicke radiometer, but built on low-cost, printed-circuit board (PCB) material using inexpensive commercial off-the-shelf parts. With a total weight of just about 2 kg (4 lbs.) and a targeted overall cost of under $100, the handheld radiometer offers great potential to Earth science applications. It could be used as a handy scientific tool for surface soil moisture measurements and as a miniature solar radio telescope.

FY 2004 Accomplishments:

During FY 2004, we completed the design and construction of the antenna, RF front-end receiver, and detector read-out circuitry. We met our minimum success criteria by demonstrating the radiometer response to outside stimuli. We successfully observed different signals while viewing cold space, the Sun, and the soil.

Two students participated in this project (see Figure 1). First, Eric Chikando, who attends Morgan State University, is a CAMRA graduate fellow. CAMRA is a university research center funded by NASA. Eric designed the RF front-end and detector read-out circuitry and has expressed interest in continuing this work as part of his doctoral thesis research. Second, Lauren Hand, an undergraduate at University of Maryland-Baltimore County, was a student intern during the summer. Hand assisted Chikando with laboratory testing, constructed the antenna, and did some parts selection for the readout circuitry. Finally, Chikando plans to submit an abstract on this work to the International Geoscience and Remote Sensing Symposium.

The design philosophy of the radiometer is to use a conventional, if not dated, architecture with low-cost parts. A version of the receiver is shown in Figure 2. Using a double-sideband, super-heterodyne Dicke architecture allowed us to use low-cost parts. For example, we do not need an RF band-definition filter, which can cost several hundred dollars. Rather, we use the double-sideband receiver with a low-pass IF filter, costing only $10. Our RF switch is a single-pole double throw (SPDT), complementary metal oxide semiconductor (CMOS) based integrated circuit surface mount (SMT) component acquired from Peregrine Inc. It offers adequate insertion loss of 1dB at frequencies up to 2GHz. The component is actuated by a transistor-transistor logic (TTL) signal generated from a 555 timer at 50% duty cycle. The amplifiers are plastic-packaged parts costing only $1 each. The printed circuit boards were manufactured through an outside vendor. The receivers are based on a super-heterodyne configuration powered through a 9-V alkaline battery and built using off-the-shelf components. All components are shielded against radio-frequency interference (RFI) using on-board shielding enclosures.

The antenna is one of the more innovative designs used in the handheld radiometer. We made the horn by covering a foam-core board frame with aluminum foil. The notched edges of the bucket walls are a quarter wavelength in size and help reduce antenna back-lobes. Directivity measurements were performed at the Goddard Automated Antenna Measurement System (GAAMS). Results from these measurements, (see Figure 3) showed close agreement with expected results.

Figure 1. Student participants, Eric Chikando (left) and Lauren Hand (right), display the completed prototype of the handheld microwave radiometer.

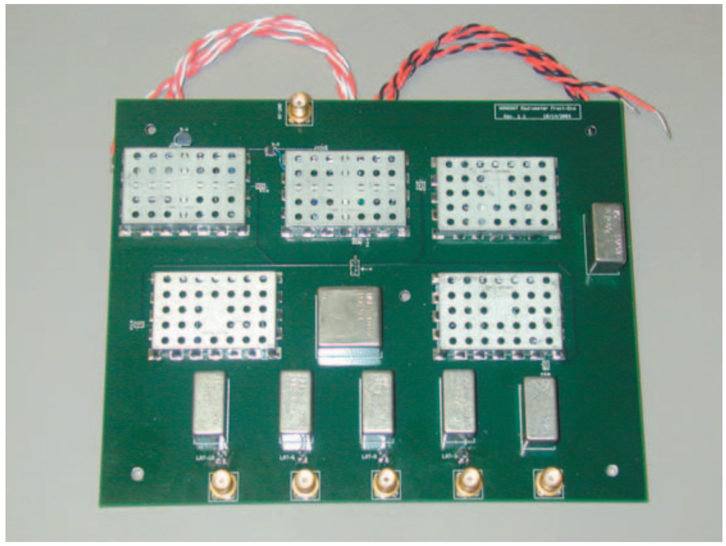

Figure 2. Receiver front-end

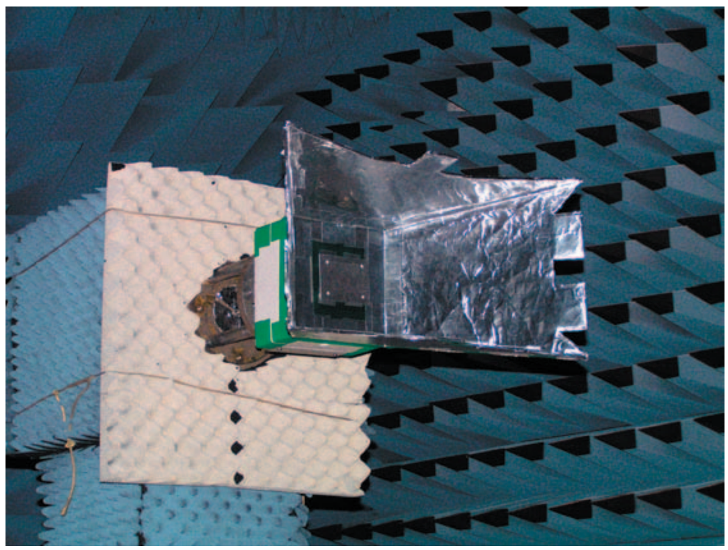

Figure 3. Radiometer antenna in anechoic chamber

Planned Future Work:

Eric Chikando plans to continue this work as part of his doctoral thesis research. Currently, the radiometer is only an "educational tool" and not a scientific instrument. Several soil scientists have expressed interest in using the radiometer to make calibrated surface soil moisture measurements. Professor Anu Dujari from Delaware State University has been working through the Minority University Space Interdisciplinary Network (MUSPIN) program to develop a scientific protocol for using the handheld radiometer to take such measurements.

Summary:

The project is developing an innovative low-cost handheld microwave radiometer for educational outreach purposes. The handheld instrument is a Dicke radiometer designed to operate at frequency of 1.413Ghz, the standard for taking soil-moisture measurements. It will be powered using a 9-V battery. This instrument has a target cost of under $100 and total weight of around 2 kg. The instrument will benefit NASA by educating students about passive microwave remote sensing. A project risk is that such an inexpensive instrument will not have the capability to be properly calibrated to yield scientifically valid measurements.