CRADA Final Report - 0660.00

BioSAR Airborne Biomass Sensor System

Robin L. Graham (PI)
Environmental Sciences Division
Oak Ridge National Laboratory
Oak Ridge, TN 37931

Patrick Johnson
American Electronics, Inc

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Abstract

This CRADA was developed to enable ORNL to assist American Electronics, Inc. test a new technology- BioSAR. BioSAR is a an airborne, low frequency (80-120 MHz ~ FM radio frequencies) synthetic aperture radar (SAR) technology which was designed and built for NASA by ZAI-Amelex under Patrick Johnson's direction. At these frequencies, leaves and small branches are nearly transparent and the majority of the energy reflected from the forest and returned to the radar is from the tree trunks. By measuring the magnitude of the back scatter, the volume of the tree trunk and therefore the biomass of the trunks can be inferred. The instrument was successfully tested on tropical rain forests in Panama. Patrick Johnson, with American Electronics, Inc received an Phase II SBIR grant from DOE Office of Climate Change to further test and refine the instrument. Mr Johnson sought ORNL expertise in measuring forest biomass in order for him to further validate his instrument. ORNL provided ground truth measurements of forest biomass at three locations – the Oak Ridge Reservation, Weyerhaeuser Co. commercial pine plantations in North Carolina, and American Energy and Power (AEP) Co. hardwood forests in southern Ohio, and facilitated flights over these forests. After Mr. Johnson processed the signal data from BioSAR instrument, the processed data were given to ORNL and we attempted to derive empirical relationships between the radar signals and the ground truth forest biomass measurements using standard statistical techniques. We were unsuccessful in deriving such relationships. Shortly before the CRADA ended, Mr Johnson discovered that FM signal from local radio station broadcasts had interfered with the back scatter measurements such that the bulk of the signal received by the BioSAR instrument was not backscatter from the radar but rather was local radio station signals.

Statement of Objectives

This Phase II SBIR project was developed in response to a DOE requirement for an airborne remote sensing system capable of the rapid measurement of sequestered carbon in aboveground terrestrial biomass. New and evolving technologies in the area of remote sensing are providing for new and innovative methods for airborne systems that relate directly to the DOE requirements. This project offered an implementation of one of these new technologies for the airborne measurement of carbon in terrestrial biomass, and additionally investigated the instrument's potential for providing airborne measures of usable board-feet per acre of standing timber for commercial and industrial purposes.

The technology used, **BioSAR™**, is a very small, low-power, down-looking, airborne synthetic aperture radar (SAR) system that operates at 80-120 MHz. At these frequencies, the leaves and small branches are nearly transparent. The majority of the energy reflected from the forest and returned to the radar is from the tree trunks which comprise ~95% of the biomass in old and heavy stands. By carefully measuring the magnitude of the returned backscatter, the volume of the tree trunks within the radar footprint can be estimated. Additional algorithms can then be applied to provide information on both biomass and carbon in tonnes/hectare and standing timber in board-feet per acre.

The system was previously designed and built under contract for the National Aeronautics and Space Administration (NASA) for the express purpose of remotely measuring woody biomass in dense tropical rain forests. Prior to this project it had been successfully tested in Panama. Since the amount of carbon in forests is strongly related to the forest woody biomass, this project was developed to test **BioSAR™** potential to provide carbon monitoring and verification for the developing carbon credit market as well as providing a measure of usable lumber in large timber stands for the commercial lumber industry.

Benefits to the Funding DOE Offices' Mission

DOE is pursuing technologies for mitigating greenhouse gas build-up. One of the options under consideration is sequestering additional carbon in forest biomass. DOE has identified accurate rapid measurement at large spatial scales (100's of square kilometers) of carbon stored in forest biomass as a high priority. This project was developed to test a novel technology developed for measuring forest biomass using SAR operating at frequencies transparent to leaves but not to large cylinders such as tree boles.

Technical Discussion of work performed by all parties

American Electronics, Inc

American Electronics, Inc was responsible for

1. Acquiring the NASA BioSAR prototype
2. Developing and building a ground-mounted external calibration device
3. Flying the prototype over forest plots identified by ORNL

4. Processing the BioSAR output and providing BioSAR data taken over those same forest plots to ORNL

ORNL

ORNL was responsible for

1. Designing the ground truth measurements needed to improve algorithms for predicting forest carbon content (Mg C/ha) from BioSAR output and testing BioSAR's potential for making commercial forest inventories.
2. Identifying forest stands suitable to BioSAR overflights.
3. Creating and measuring the carbon content of forest plots designed to test BioSAR.
4. Providing accurate geographic coordinates of plots to American Electronics, Inc so they could develop flight plans.
5. Statistically analyzing the relationship of BioSAR data taken over the specified forest plots to develop algorithms to predict forest carbon content from BioSAR data and evaluate BioSAR's potential use for commercial forest inventories.

The above tasks were accomplished between Oct 2002 and March 2004. Three forest areas were used for testing the BioSAR system - the Oak Ridge Reservation, Weyerhaeuser Co. commercial pine plantations in North Carolina, and American Energy and Power (AEP) Co. hardwood forests in southern Ohio. The main fieldwork (forest biomass measurements) and BioSAR overflights were conducted during the spring and summer of 2003. Processing of the raw BioSAR data and statistical analysis of the processed BioSAR data with ground truth forest biomass data took place in winter of 2003-2004. Unfortunately when the BioSAR data were processed it was discovered that regional radio stations had created interference and the collected data were contaminated by these radio station broadcasts. The radar frequencies which were used by the BioSAR system at each site had been approved by the FAA. They had been specifically selected to not overlap with any of the frequencies of the local radio stations so as to not interfere with the radio station broadcasts. It appeared that radio stations in the region were using higher power levels than previously reported and thus their signals extended further than had been predicted. We found that the processed radar returns picked up by the BioSAR system at a given location (e.g., ORNL, Tennessee) had essentially the same value, regardless of forest being overflown. The radar responses did not reflect changing biomass; rather they reflected the fairly constant level of FM broadcast power seen across the area of operations. Thus no improvements could be made in the BioSAR algorithms for measuring forest biomass, forest carbon or forest board feet.

Commercialization possibilities

The study highlighted the challenges of using a SAR with FM frequencies in areas populated with FM radio stations. In tropical Panama where BioSAR had been previously tested, radio interference was not present due to the remote nature of the forest over which BioSAR was flown. On the basis of this study, BioSAR still needs more testing before a commercial evaluation can be made and a work around to radio station interference must be found.

Plans for future Collaboration

As of 2006, American Electronics, Inc was still developing BioSAR and had received two additional SBIRs to support that development. ORNL was not a participant in those SBIRs as the type of support ORNL provided was not needed and the ORNL PI was engaged in other activities.

Conclusions

The study achieved its interim goals. ORNL met its commitment to the project. It was unfortunate that the interference by local radio stations was not identified until after the overflights had been made. The potential of the BioSAR technology for measuring forest biomass and timber volume was neither supported nor discredited by the current study.

Final Report Certification
for
CRADA Number 0660.00

Between

UT-Battelle, LLC

and

Zimmerman Associates, Inc.
(Participant)

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For the Participant:

Patrick W. Johnson

(Name)

SR. VP, R&D, Zimmerman Assoc., Inc.

(Title)

5/24/07

(Date)