THE MICROASAR EXPERIMENT ON CASIE-09

David G. Long[1], *Evan Zaugg*[1], *Matthew Edwards*[2], *James Maslanik*[3]

[1]Brigham Young University, [2]ARTEMIS, Inc., [3]University of Colorado

1. INTRODUCTION

In the summer of 2009, a small, low power SAR was flown on a small, unmanned aircraft system (UAS) as part of the Characterization of Arctic Sea Ice Experiment 2009 (CASIE-09) [1] over the Arctic Ocean from Svalbard Island. The goal of the mission was to measure ice roughness in support of research into monitoring ice thickness and ice age. The C-band SAR instrument, known as microASAR, collected 19.8 hours of SAR image data over five UAS flights of varying length from 6-10 hours long. The UAS was the NASA Sensor Integrated Environmental Remote Research Aircraft (SIERRA) [2]. This paper briefly describes the microASAR, its role in CASIE-09, and presents initial SAR results.

2. MICROASAR AND THE SIERRA UAS

Synthetic aperture radar (SAR) can be a useful tool for sea ice observation, but has traditionally been large and expensive. The compact microASAR builds on the design of the BYU microSAR [3], but is a much more robust and flexible system [4]. The microASAR uses a linear frequency-modulated continuous-wave (LFM-CW) transmit signal generated by a direct digital synthesizer (DDS) chip. The system is bistatic, so that it transmits and receives at the same time using two different antennas. This enables long transmit chips to maximize the SNR while minimizing peak transmit power. The return signal is mixed down with a frequency-shifted copy of the transmit signal (analog dechirp) with an all-digital final IF stage. Internal filtering minimizes transmit/receive signal feedthru. Raw data is stored to compact flash (CF) disk. Using 32 MB CF disks, over two hours of SAR data can be recorded. The microASAR transmit bandwidth is 160 MHz, yielding a nominal range resolution of approximately 1 m. Table 1 provides a summary of the microASAR specifications.

A key goal of CASIE-09 was to provide fine spatial resolution over difficult to access locations in the high Arctic. Satellites cannot provide the desired simultaneous combination of sensor types and resolution. Piloted aircraft typically fly too high and too fast to yield the fine-scale sampling rates and mapping patterns required by our project. UAS-based measurements can be made a low speed and low altitude in dangerous Arctic conditions without putting humans at risk.

Table I

microASAR Specifications

Physical Specifications	
Transmit Power	30 dBm
Supply Power	< 35 W
Supply Voltage	+15 to +26 VDC
Dimensions	22.1x18.5x4.6 cm
Weight	2.5 kg
Radar Parameters	
Modulation Type	LFM-CW
Operating Frequency Band	C-band
Transmit Center Frequency	5428.76 MHz
Signal Bandwidth	80-200 MHz (variable)
PRF	7-14 kHz (variable)
Radar Operating Specifications	
Theoretical Resolution	0.75 m (@ 200 MHz BW)
Operating Altitude	500-3000 ft
Max. Swath Width	300-2500 m (alt. dependent)
Operating Velocity	10-150 m/s
Collection Time (for 10GB)	30-60 min (PRF dependent)
Antennas (2 required)	
Type	2 x 8 Patch Array
Gain	15.5 dB
Beamwidth	8.5°x50°
Size	35x12x0.25 cm

In CASIE-09 the microASAR was flown aboard the NASA SIERRA UAS. With a relatively large payload capacity, efficient mission planning software, and in-flight programmable autopilot, the SIERRA is well-suited for the long-duration missions used in the CASIE-09 experiment. Some of the other sensors on the UAS included two optical cameras, two pyrometers, a up/down-looking shortwave spectrometer, high-quality inertial measurement unit (IMU), and a laser profilometer system consisting of two down-pointing lasers, a medium-quality IMU, and differential-capable GPS receiver [4]. The UAS provided GPS position data to the microSAR where it was included in the SAR processing stream. A video camera was mounted to view in the same direction as the microASAR, providing optical imagery coincident with the SAR swath. The UAS was flown a low altitude (typically between 600’ and 1500’). While the low altitude limits the microSAR swath width, it also benefits the SAR measurement SNR. The UAS flights originated from Ny-Alesund, Svalbard, providing an acceptable flight range to the sea ice pack within Fram Strait to the west. Ny-Alesund offered relatively close access to ice with a range of thicknesses, age, and ridging characteristics. The ice in Fram Strait is transported from the central Arctic Ocean, thus providing an opportunity to sample a variety of ice types ranging from first-year ice to ice that is several years old. Five science flights covering 2923 km of sea ice were flown in July 2009 as part of CASIE-09. Flight planning took advantage of near real-time ice imaging from QuikSCAT, AMSR, MODIS and AVHRR.

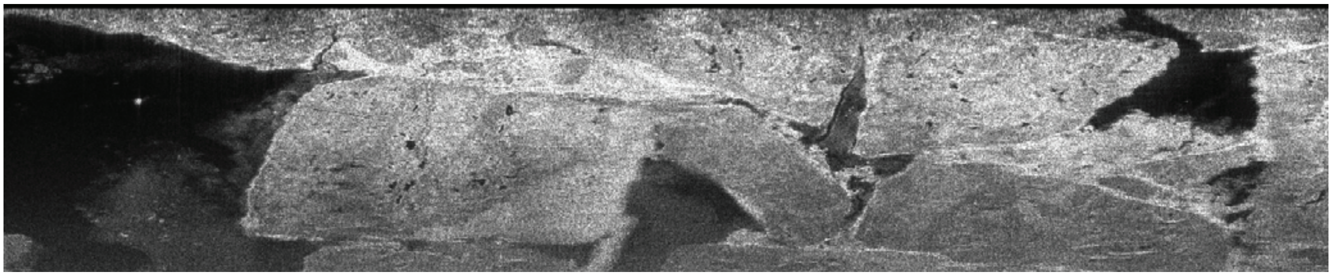

Figure 1. Sample microASAR image from CASIE-09. Nadir is along the top of the image. The UAS flew from left to right. The incidence angle varies from zero at the top to over 60 deg as the bottom of the image. The image dimensions are approximately 3.5 km by 1 km. The multi-looked pixel resolution is 0.5 m in azimuth by 1 m in range.

3. SAR IMAGES

Raw microASAR data was processed into SAR images using the Frequency Scaling Algorithm (FSA), a version of the Chirp Scaling Algorithm (CSA) adapted for LFM-CW SAR operation. Azimuth resolution after multi-looking is 0.5 m. Unfortunately, quality of the GPS data has been a limiting factor in applying motion compensation [5], but the smooth flight of the SIERRA UAS enables production of well-focused images.

Raw data was divided into 1 min segments and separately processed into multi-looked image segments typically 3.5 km long in the along-track dimension by 1.2 km wide in the cross-track dimension. The processed SAR images show a variety of surface features from open ocean to dense pack ice. Features visible in the SAR imagery, as confirmed by the corresponding video, include ridges, rubble fields, brash ice, leads, and melt ponds. A sample microASAR image is shown in Fig. 1. Additional images will be provided in the final paper. Creation of kmz files enables convenient browsing in Google Earth.

SAR imagery compares well to the simultaneous optical imagery, samples of which will be provided in the final paper. Both optical and microASAR images are being compared to spaceborne radiometer and scatterometer observations to better understand the relationship between roughness and ice conditions during the summer ice melt period. The microASAR image data set includes overlapping images with the wide incidence angle range, which can help better understand the scattering mechanisms of the features observed.

4. REFERENCES

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