TRI-FREQUENCY SYNTHETIC APERTURE RADAR FOR THE MEASUREMENTS OF SNOW WATER EQUIVALENT

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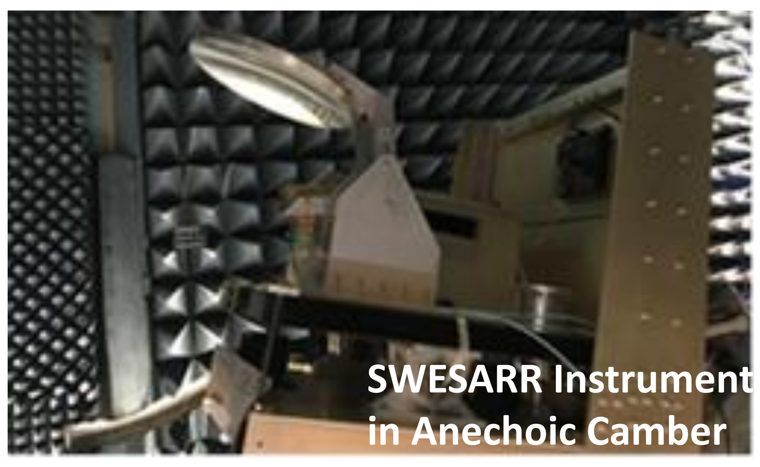
INTRODUCTION

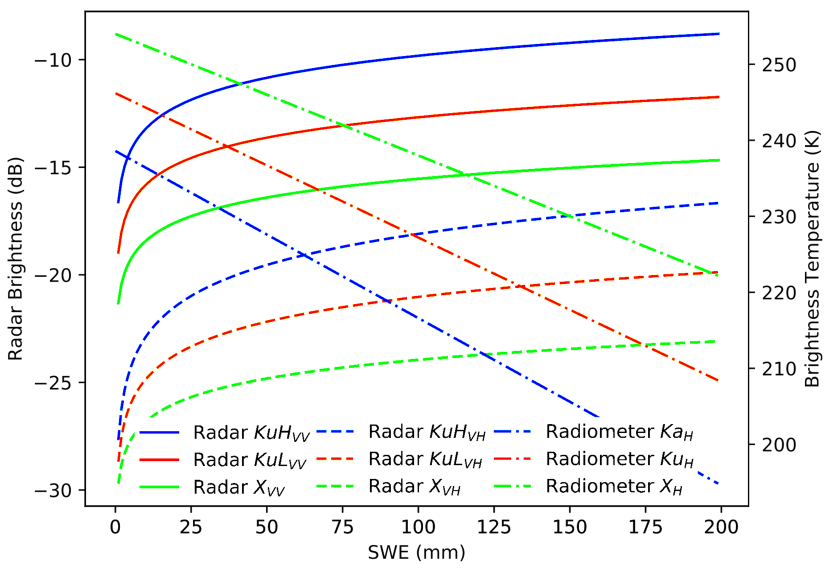
SWESARR (Snow Water Equivalent Synthetic Aperture Radar and Radiometer) is an airborne instrument developed at the NASA Goddard Space Flight Center for the retrieval of Snow Water Equivalent.

SWESARR was specifically designed to measure co-located active and passive signals using a high resolution and multi-frequency Synthetic Aperture Radar (SAR) and a multi-frequency radiometer.


SWESARR Instrument in Anechoic Camber

SWESARR's Synthetic Aperture Radar (SAR) system is made up of three independent radar units that operate in the X, Ku-Low, and Ku-High bands with bandwidths up to 200 MHz, and acquires data in two polarizations (dual-polarization radar).

The difference in sensitivity of the backscatter signals to snow microstructure, in conjunctions with radiometer measurements, permits an accurate estimation of the snow water equivalent (SWE).



SCIENCE OBJECTIVE

SWE, the measurement of how much water is present as snow, is a very important parameter for water resource management and climate studies. One-sixth of the world's population (1.2 billion people) rely on seasonal snowpack and glaciers as a source of fresh water. Hence, developing the tools to remotely measure SWE is one of NASA's priorities.

To that end, SnowEx, a multi-year airborne snow campaign, seeks to test the performance of various instruments to get a better understanding of how much water is stored in the Earth's terrestrial snow.


SnowEX Field Site

SWESARR's unique measurement approach can provide critically needed data for the accurate estimation of SWE and make a valuable contribution to future SnowEx efforts. In addition, SWESARR will provide a test-bed for measurement techniques that can be extended to satellite observation, setting a path for future spaceborne snow missions.

RADAR DESCRIPTION

SWESARR's radar system transmits vertically polarized signals at 9.65 GHz, 13.6 GHz, and 17.25 GHz, and receives vertically and horizontally (VV, VH) polarized backscattered returns.

Table 1: Radar Main Characteristics

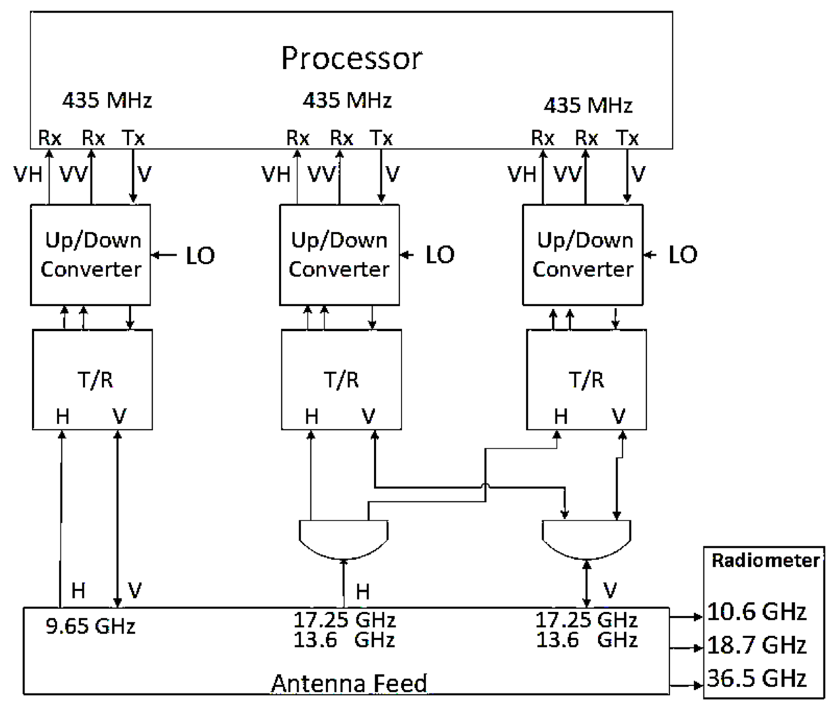
Frequency (GHz)	9.65 , 13.6, 17.25
Nominal Bandwidth (MHz)	140
Polarization	VV, VH
Nominal PRF (kHz)	1
Look Angle (degrees)	45
Pulse Width (μs)	10

Waveform generation and data acquisition is performed by a custom FPGA-based multi-channel Radar Digital Unit (RDU). The RDU is fully programmable and permits the configuration of several radar main parameters, including waveform type, bandwidth, pulse repetition frequency (PRF), and pulse width.

The antenna pointing, nominally set at 45 degree depression angle and perpendicular to the flight track, can also be mechanically adjusted.

RADAR ARCHITECTURE

SWESARR's three radar units operate synchronously and coherently at an IF frequency of 435 MHz. Dedicated single stage up-conversion and RF signal conditioning is employed at each of the bands.



The three radar units share an offset-fed reflector antenna with the radiometer. The reflector is fed by a broadband "current sheet array" feed allowing the coincident measurement of nine active and passive signals in the X-, Ku- and Ka-bands (between 9.6 GHz and 37 GHz).

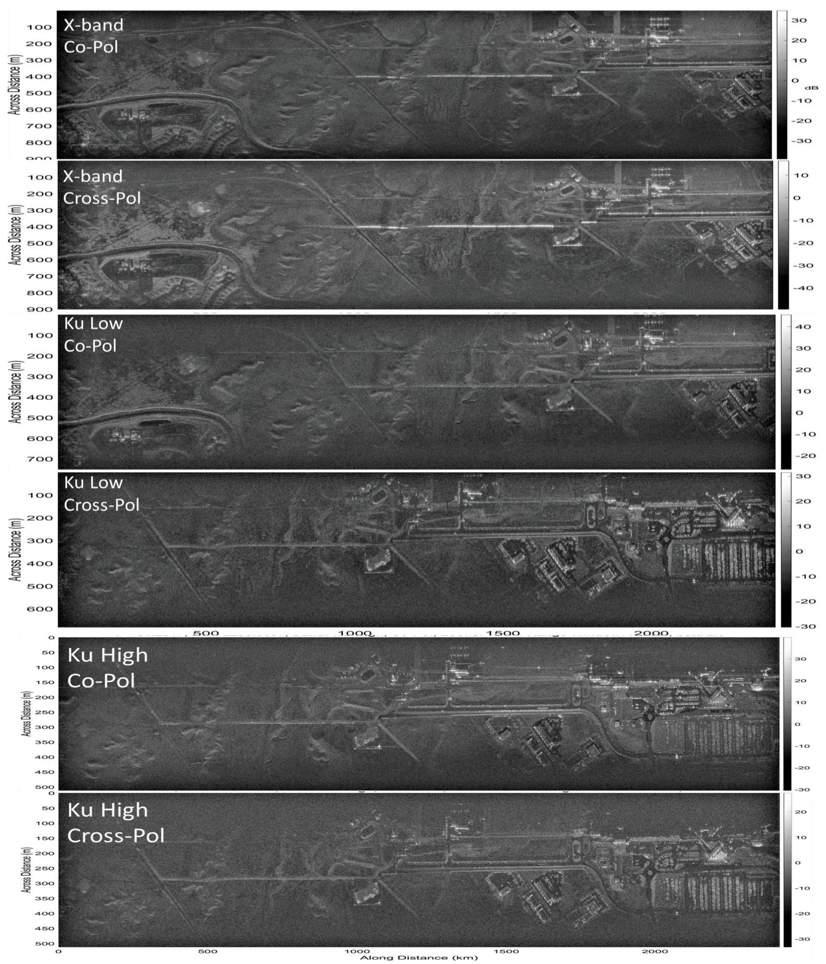
FIRST TEST FLIGHTS

SWESARR's radar development was completed in Oct 2018, after which it conducted its first test flights on a Twin Otter aircraft over areas of Grand Junction, Colorado in the Rocky Mountains region, Southwest United States.


SWESARR Integration to Twin Otter Aircraft

The area covered during the flights included the Grand Junction airport, where four trihedral corner reflectors were deployed for radar calibration.

The 1.8 m × 2 m (10 looks) Co-pol (VV) and Cross-pol (VH) images shown here where acquired from an altitude of 1500 m above the ground. All images were acquired simultaneously.



RADAR PERFORMANCE

The images of the Airport were used to provide a preliminarily assessment of the SAR performance.

The *Single Look* impulse response of the 0.9 m CR are shown, where a Kaiser smoothing window (2.5 beta value) was used in both range and azimuth dimensions. The performance analysis is summarized in table 2.

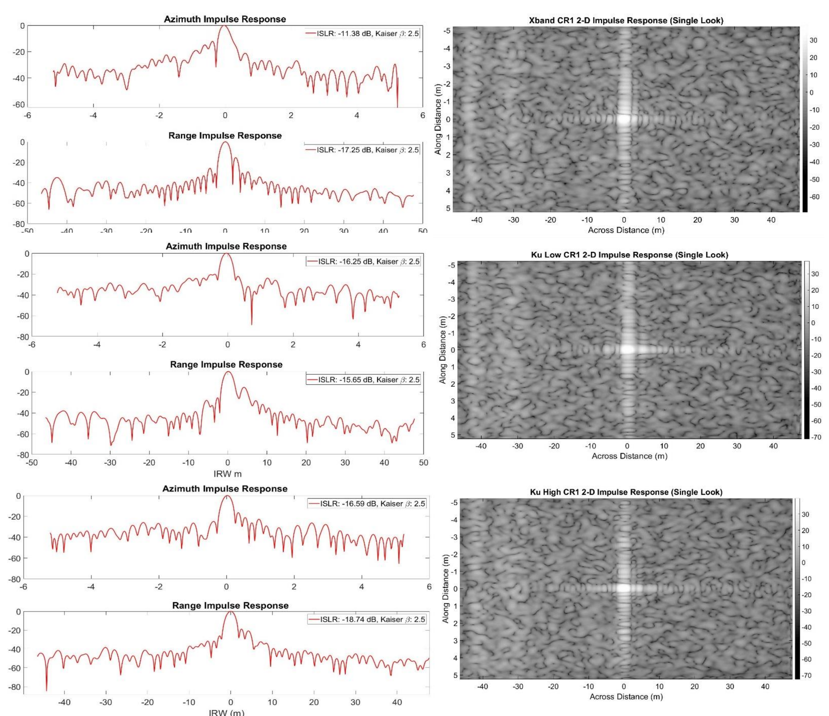


Table 2: Image Quality (Expected Vs. Measurement)

	Exp.	Meas.	Exp.	Meas.	Exp.	Meas.
Frequency (GHz)	9.65		13.6		17.25	
Res: Rng (m) × Az (m)	1.8 × 0.2	1.8 × 0.2	1.8 × 0.2	1.8 × 0.2	1.8 × 0.2	1.8 × 0.2
NESO (dB) (1.5 km alt.)	-33	-34	-32	-29	-30	-33
Dynamic Range (dB)	66	62	66	62	66	53
Cross-Pol Iso. (dB)	> 25	21.3	> 27	24	> 28	29
PSLR (dB)	≤ -20	17.25	≤ -20	-15	≤ -20	-18
ISLR (dB)	≤ -17	-16	≤ -17	-16	≤ -17	-18

CONCLUSION AND OUTLOOK

SWESARR's radar was successfully demonstrated during its first test flights. Initial analysis of the data acquired during the campaign indicated the SAR operated successfully, meeting the design performance metrics. The radar will fly again in November 2019 and February 2020 as part of the SnowEx campaigns.