The Ultra-Wideband Software-Defined Radiometer (UWBRAD) for Ice Sheet Internal Temperature Sensing: Instrument Status and Experiment Plans

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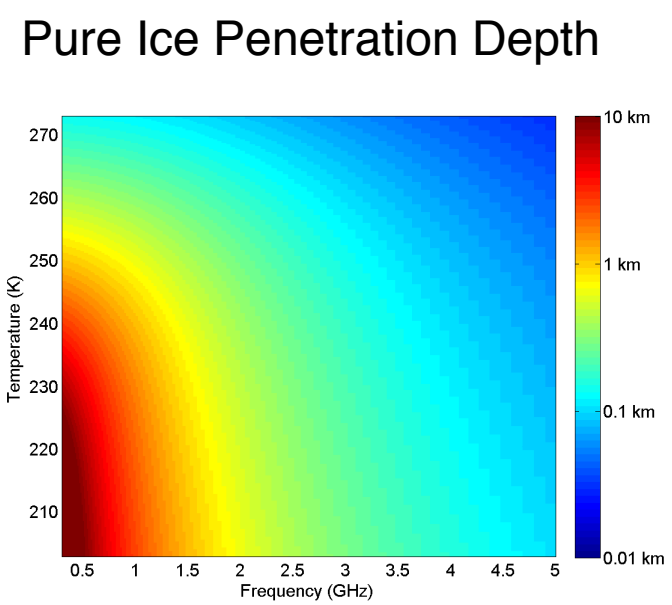
Motivation

- Understanding dynamics of Earth's ice sheets important for future prediction of ice coverage and sea level rise
- Extensive past studies have developed a variety of sensing techniques for ice sheet properties, e.g. thickness, topography, velocity, mass, accumulation rate,…
- Internal temperature influences stiffness, which influences stress-strain relationship and therefore ice deformation and motion
- Limited capabilities for determining ice sheet internal temperatures at present
  - Available from small number of boreholes
- Can ice sheet internal temperatures be determined using microwave radiometry?

Ultra Wide Band RADiometer (UWBRAD)

- Penetration depth in ice varies with frequency
  - larger for lower frequencies
  - up to 10 km at 500 MHz
- Using a multi-frequency radiometer can provide information from different depths of the ice sheet
- We have proposed the "ultra-wideband software defined radiometer" to perform multi-frequency ice sheet observations



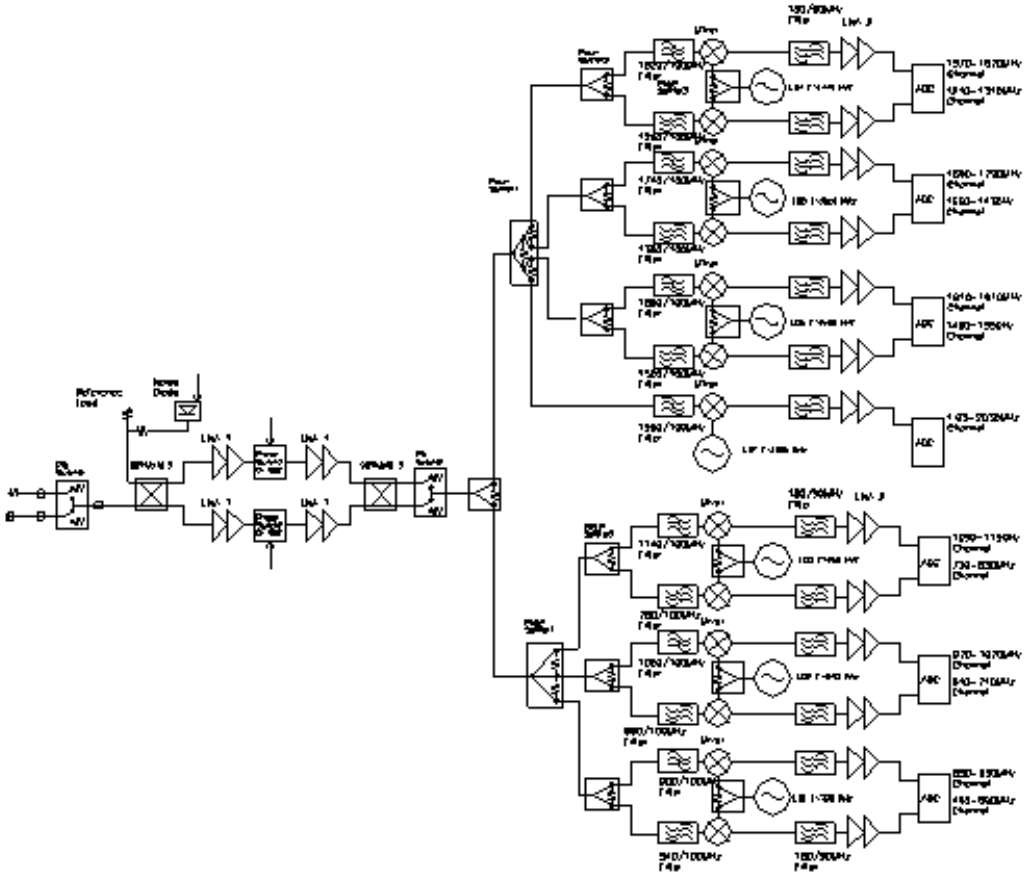
Ultra Wide Band RADiometer (UWBRAD)

- UWBRAD=a radiometer operating 0.5 – 2 GHz for internal ice sheet temperature sensing
- Requires operating in unprotected bands, so interference a major concern
- Address by sampling entire bandwidth (in 100 MHz channels) and implement real-time detection/mitigation/use of unoccupied spectrum
- Supported under NASA 2013 Instrument Incubator Program
- Goal: deploy at DOME-C, Antarctica tower in Nov 2015 and in Greenland flights in 2016
- Retrieve internal ice sheet temperatures and compare with in-situ core sites

Freq (GHz)	0.5-2, 12 x 100 MHz channels
Polarization	Single (Right-hand circular)
Observation angle	Nadir
Spatial Resolution	1 km x 1 km (1 km platform altitude)
Integration time	100 msec
Ant Gain (dB) /Beamwidth	11 dB 30°
Calibration (Internal)	Reference load and Noise diode sources
Calibration (External)	Sky and Ocean Measurements
Noise equiv dT	0.4 K in 100 msec (each 100 MHz channel)
Interference Management	Full sampling of 100 MHz bandwidth in 16 bits resolution each channel; real time “software defined” RFI detection and mitigation
Initial Data Rate	700 Megabytes per second (10% duty cycle)
Data Rate to Disk	<1 Megabyte per second

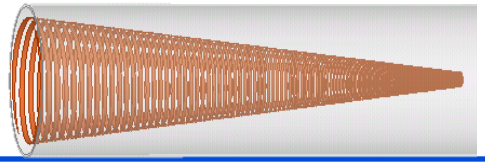
Radiometer Design

- The radiometer is composed of three major subsystems:
  - Front End



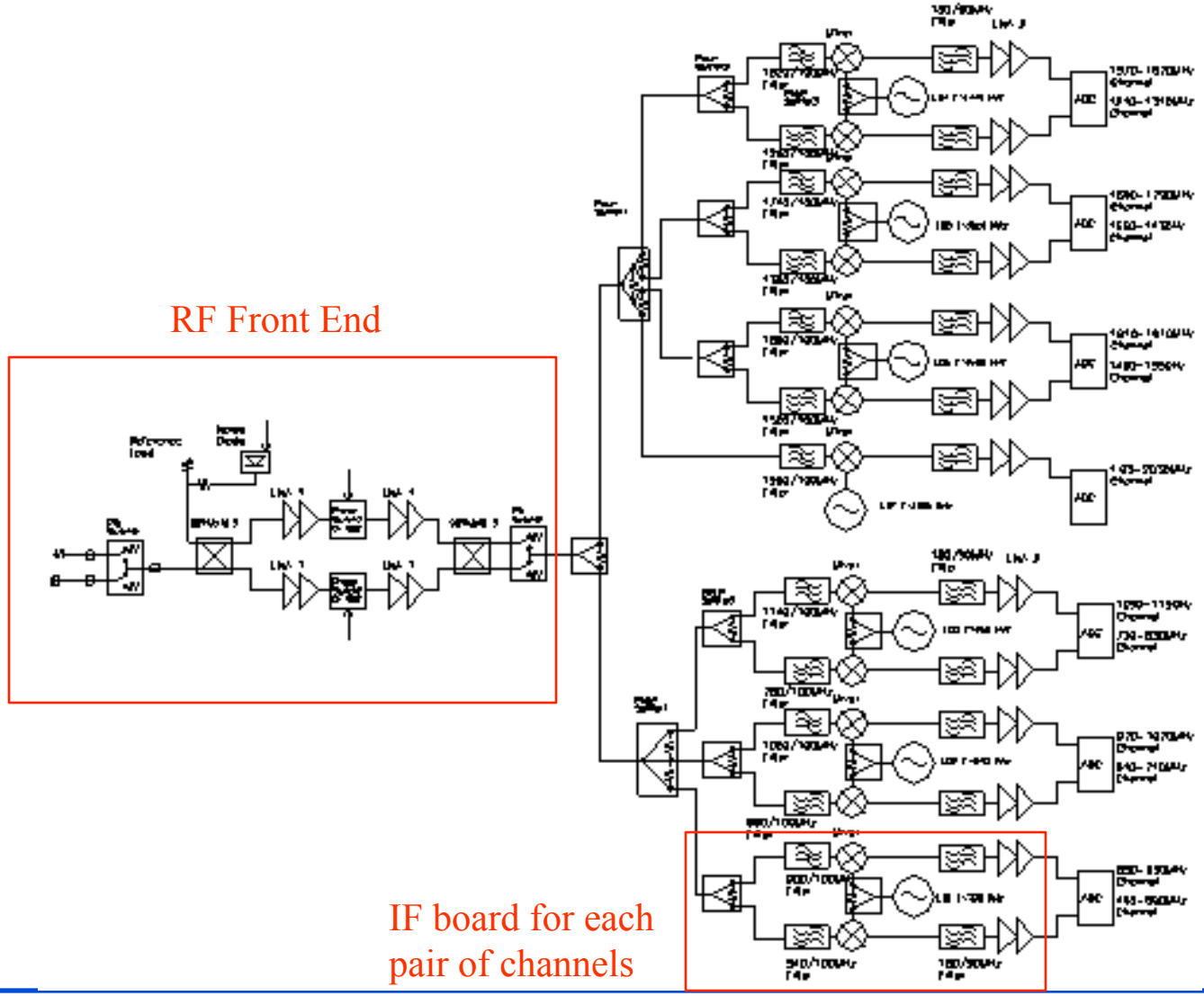
  - Digital Backend

  - Antenna



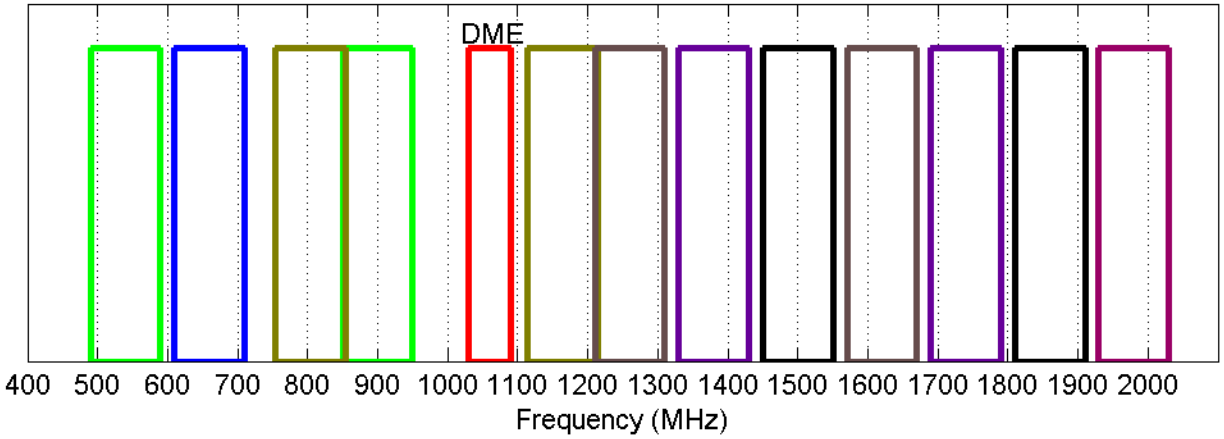
Front End

- Single RF front end with separate dual-channel IF board for each pair of channels

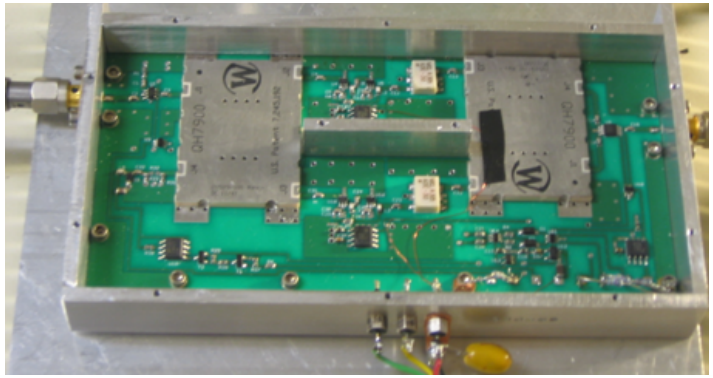


Frequency Plan and Progress

- Based on RFI considerations, the 0.5-2 GHz frequency bandwidth is divided into 12 separated 100 MHz channels; avoiding aircraft DME interference

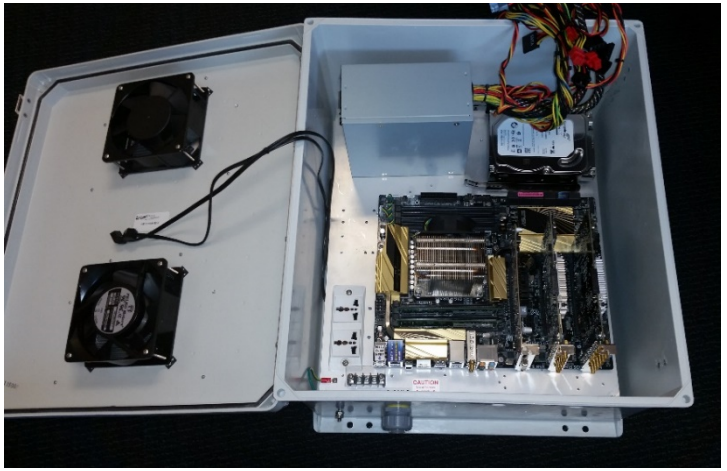


- Radiometer front end construction and test complete; IF board build and test near completion



Back End

- Digital Subsystem based around the ATS9625 card from AlazarTech, Inc:
  - 2 channel, 250 MSPS,16 bit/sample data acquisition card
  - Achieves high throughput to host PC
  - RFI processing performed on host PC

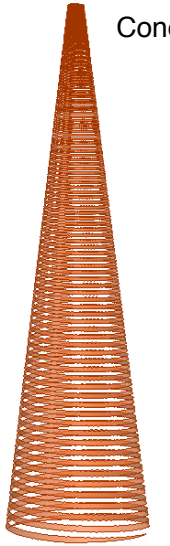


- Each board can handle 2 100 MHz channels
- 6 boards used for 12 channels
  - 3 PC's + One host PC
- PC's acquire data, perform 1K FFT, compute kurtosis in time and frequency domains, and perform multiple RFI detection and filtering steps:
  - Cross frequency
  - Pulse detection
  - Kurtosis detection
  - ~10% duty cycle overall: acceptable for planned deployments

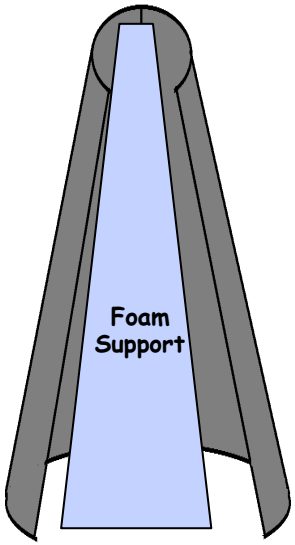
Antenna Design

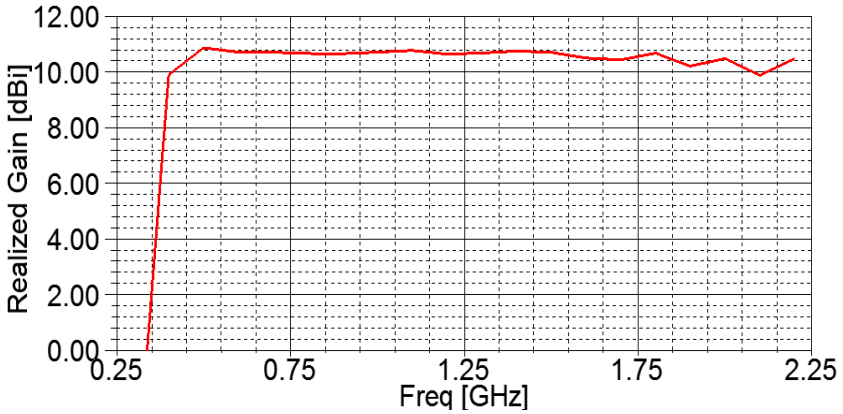
- Conical Logarithmic Spiral Antenna: Circular Polarization
- Stable and Moderate Gain (~ 10 dB) over frequencies
- 60º Beamwidth: acceptable for low altitude deployment

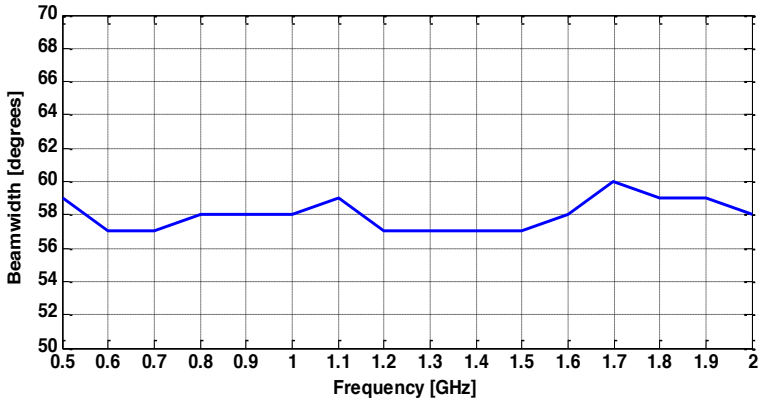
Diameter: 1.1 inches



Diameter: 10 inches

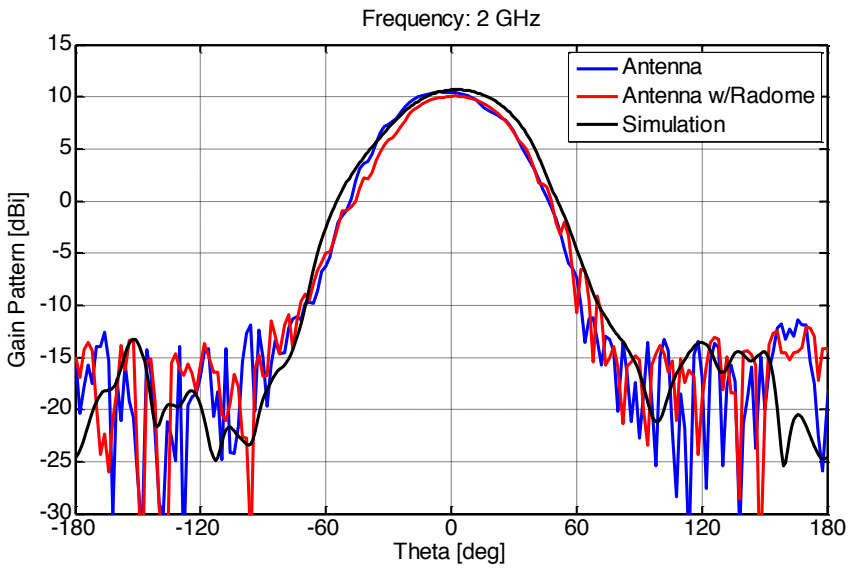






Antenna Measurement

- Antenna built and tested; also with and without radome

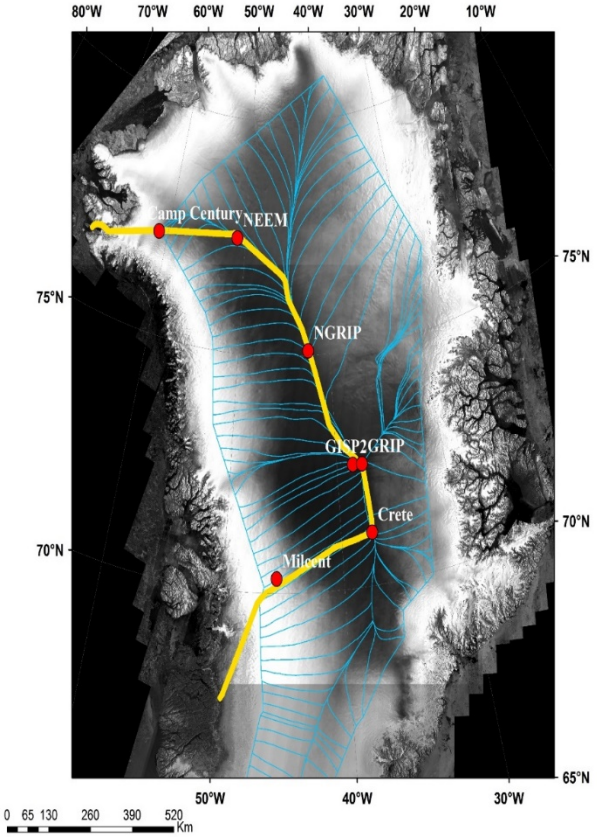


- Performance shows close match to simulations
- Pattern nearly uniform versus frequency

Retrieval Studies

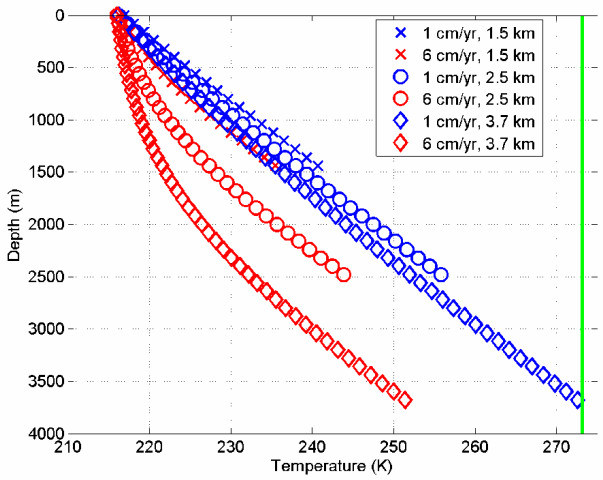
- UWBRAD will be deployed in 2016 in airborne observations of the Greenland ice sheets
- Follow paths of measured ancillary data where possible (e.g. Operation IceBridge ice thickness)
- Tie to the 4 deep ice cores in north and north central Greenland
- April or October deployment to avoid surface melt
- Locate near ice divides to simplify ice dynamics
- Concentrate on dry snow zone to minimize layering effects in melt facies
- Deploy on Ken Borek Airlines DC-3T Aircraft

  5 days/ 40 flight hours



Retrieval Studies

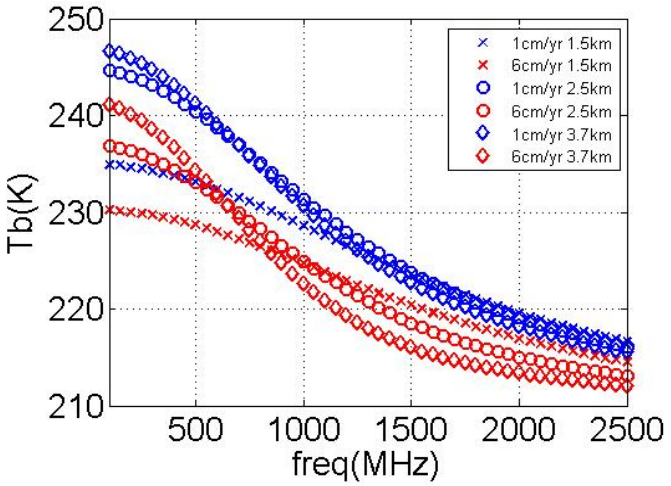
Ice Sheet Internal Temperature depends on ice sheet height, Accumulation Rate, Geothermal Heat Flux



Brightness Temperature modelling with DMRT-ML

Dome-C example

Ice Sheet Internal Temperature variations induce Brightness Temperature variations

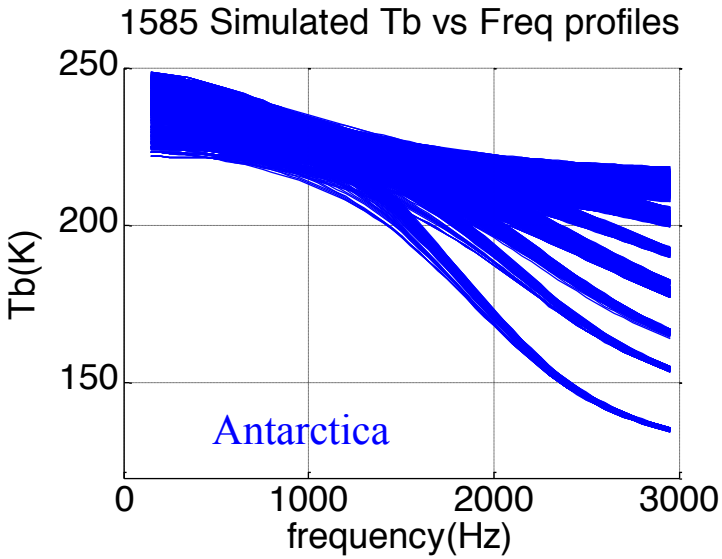


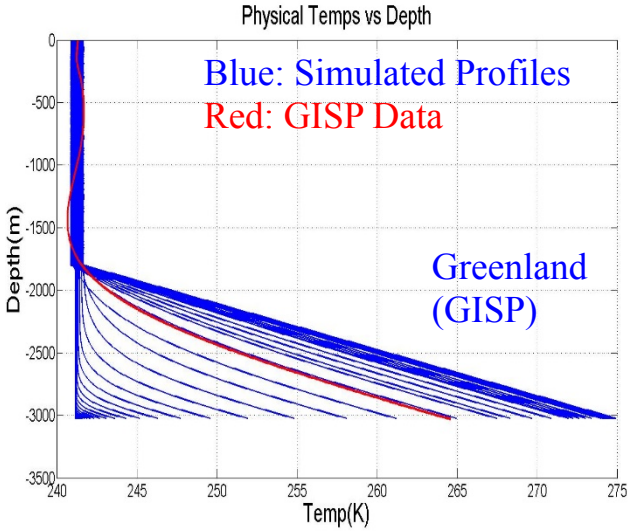
- DMRT-ML model (Picard et al, 2012) widely used to model emission from ice sheets (Brucker et al, 2011a) and snowpacks (Brucker et al, 2011b)
  - Uses QCA/Percus-Yevick pair distribution for sticky or non-sticky spheres
  - RT equation solved using discrete ordinate method
  - Need layer thickness, temperature, density, and grain size for multiple layers

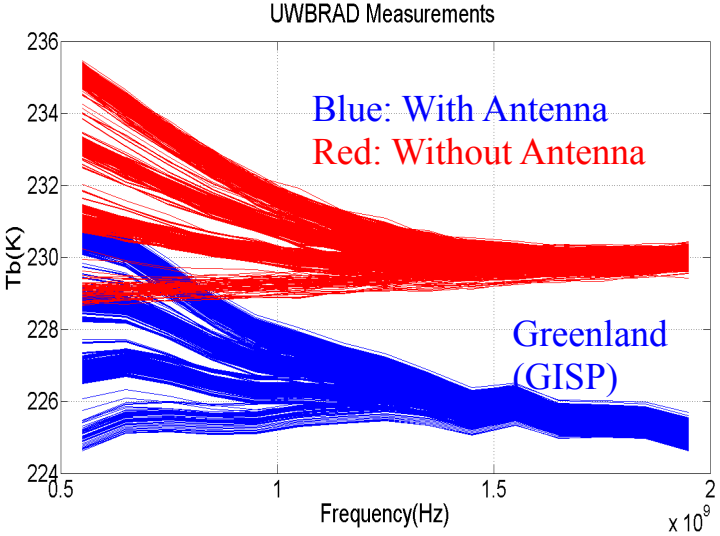
Initial Retrieval Studies for Greenland

- Antarctica:
  - Cold Surface Temperatures
  - Low accumulation rates
  - Strong changes in TB vs. frequency

- Greenland:
  - Warmer Surface Temperatures
  - Higher accumulation rates in Greenland
  - Smaller changes in TB vs. frequency
  - Still observable by UWBRAD

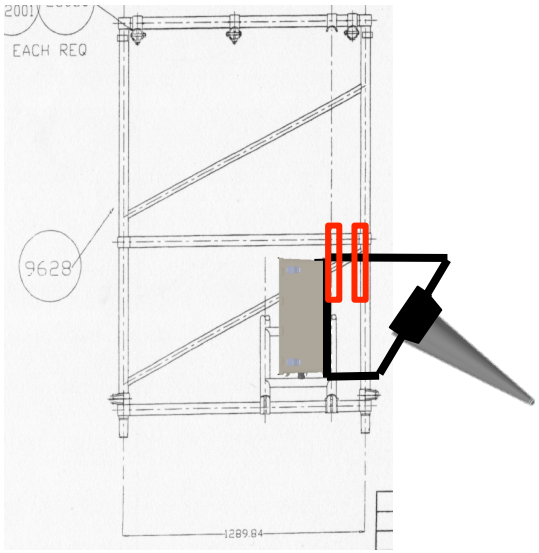




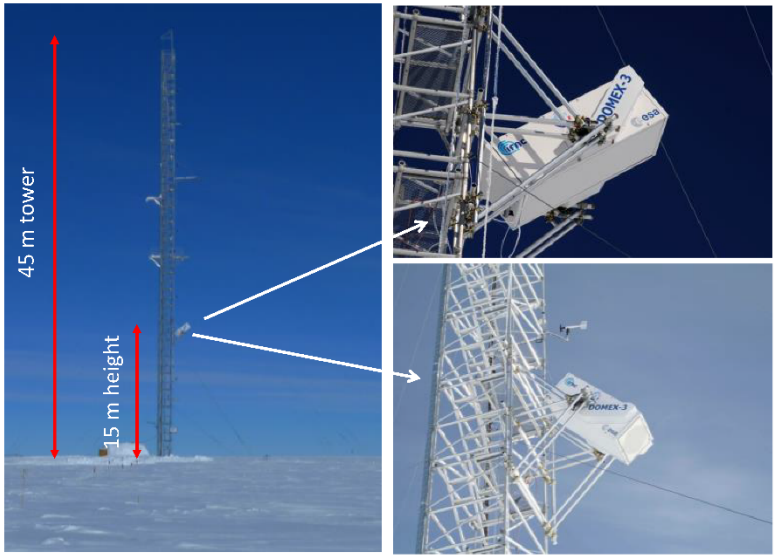


UWBRAD Deployment

- Also deploying a 4 channel UWBRAD in Antarctica at Dome-C between November 2015 and January 2016



DOMEX3 - Set Up



- Configuration: One incidence angle, 4 frequencies covering 0.5-2 GHz, 30-45 days campaign

Conclusions

- Multi-frequency brightness temperature measurements can provide additional information on internal ice sheet properties
  - Increased penetration depth in pure ice and reduced effect of scatterers as frequency decreases

- UWBRAD making good progress toward deployment
  - Delivery of 4 channel unit August 1st for November 2015 DOME-C campaign
  - Development of 12 channel unit on scheduled for Greenland flights Spring 2016