Goddard Space Flight Center

Digital
Beamforming
Synthetic
Aperture
Radar

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Rafael F. Rincon
NASA/ GSFC
Microwave Instruments Technology Branch (Code 555)

ESTO
Earth Science Technology Office

Introduction

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- For several years NASA/Goddard Space Flight Center (GSFC) has been investing through its Internal Research and Development (IRAD) program in the development of a new generation airborne L-Band radar system known as the Digital Beamforming Synthetic Aperture Radar (DBSAR).

- DBSAR combines advanced radar technologies, real-time on-board processing, and innovative signal processing techniques in order to enable multi-mode radar techniques in a single radar architecture in support of Earth Science and planetary applications.

DBSAR during Calibration in Anechoic Chamber

DBSAR integrated to NASA P3 aircraft

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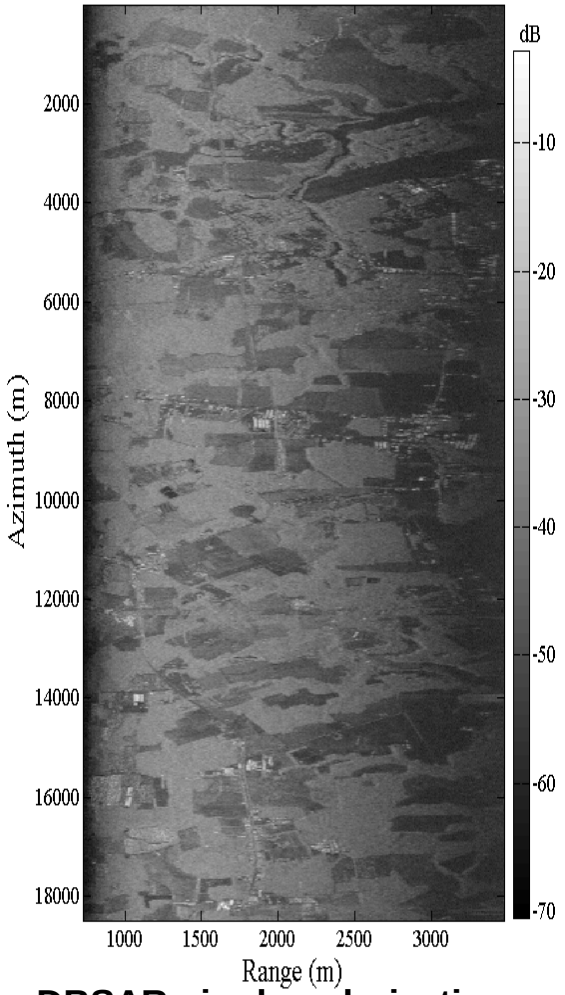
Introduction

- DBSAR's first campaign took place in the fall of 2008 when the system successfully collected multi-mode data over areas of scientific interest.

- Although DBSAR's original configuration had a dual-polarization antenna, the rest of the system was designed for single polarization operation.

- The polarimetric capability in DBSAR would enable the measurement of the full scattering matrix which provides more accurate estimates of important scientific parameters.



DBSAR single polarization image over NASA/WFF (resample to 10 m x 10 m resolution)

DBSAR Architecture

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RADAR

Frequency	1.26 GHz
Maximum Bandwidth	20 MHz
PRF	40 Hz - 10 KHz
Pulse Width	1 – 100 μs
Number of Transmitters	8
Output Power	16 W
Accuracy	< 0.7 dB
Beam Steering Angles	> ± 50 degrees

ANTENNA

Type	Microstrip Patch
Number of Patches	80
Bandwidth	20 MHz
Polarization	Dual
3 dB Beamwidth	16 Degrees*
Two-Way Side Lobes	< -46 dB*
Antenna Gain	21 dB*

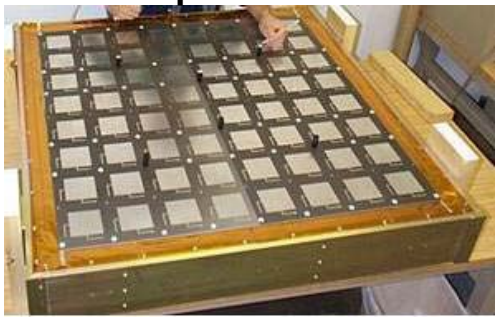
** Cosine Taper

MISC

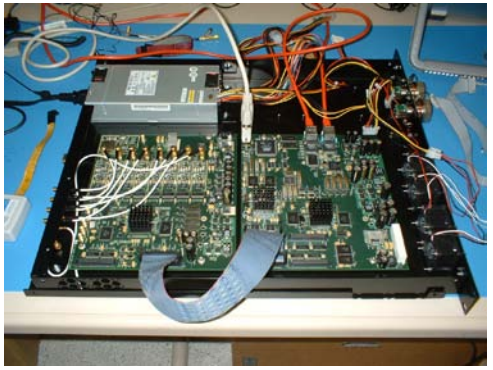
Dimensions (m)	1.2 x 1 x 0.5
Power Draw (W)	350
Weight (kg)	106

DBSAR Transceivers

Microstrip Patch Antenna



Data Acquisition and Processor



- Custom design
- Fully Reconfigurable
- Three Stratix II FPGAs
- Eight A/D converters
- Six SRAMs
- ARM microcontroller
- 1-Gb Ethernet interface
- Size (cm): 17 x 24 x 4
- Power: 94 W max

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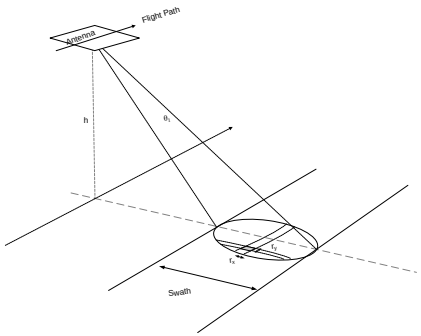
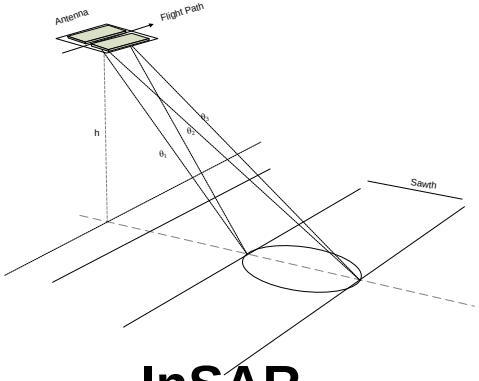
DBSAR Operational Modes

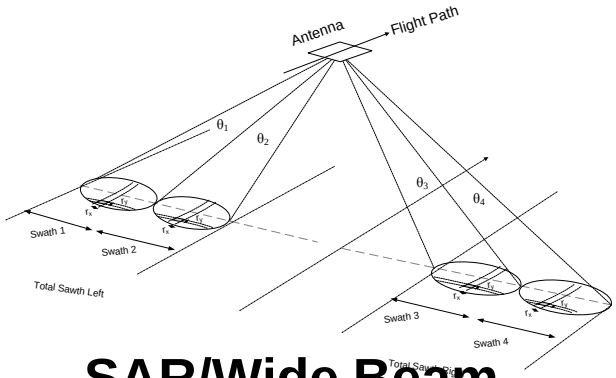
- **Current operational modes include scatterometry over multiple antenna beams, several modes of Syntehtic Apeture Radar (SAR), and Altimetry.**



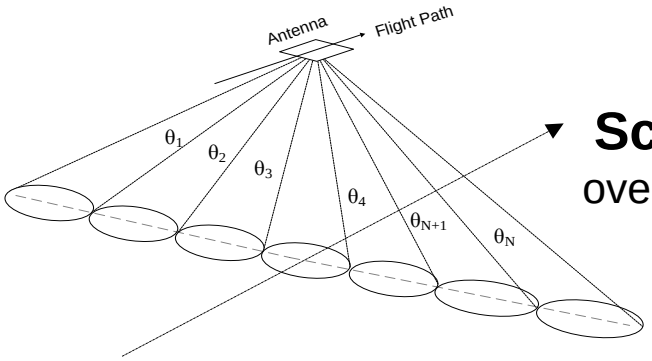
SAR/ Narrow beam



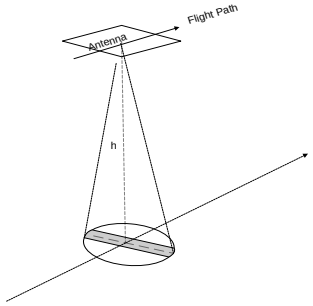
InSAR
Single Pass



SAR/Wide Beam
Both sides of the track



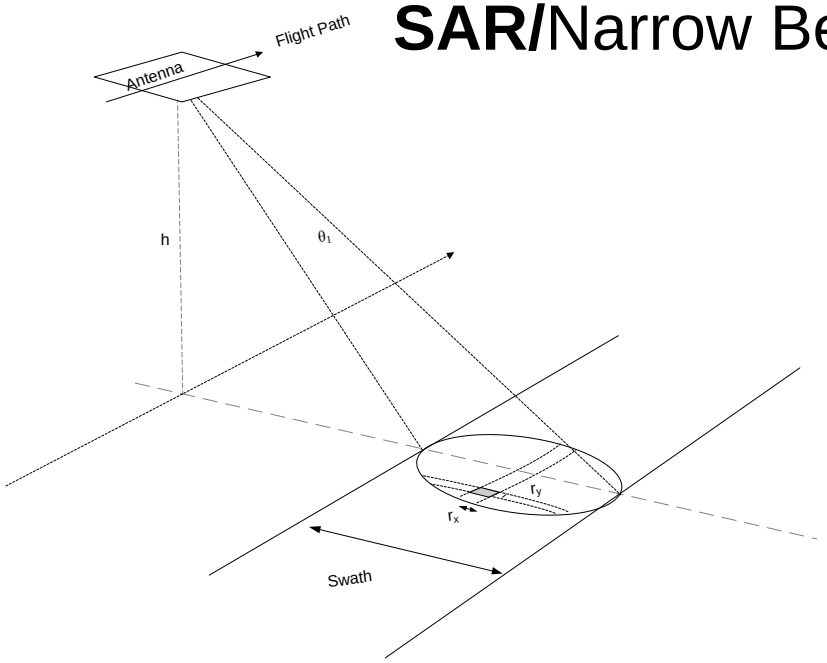
Scatterometry
over multiple beams

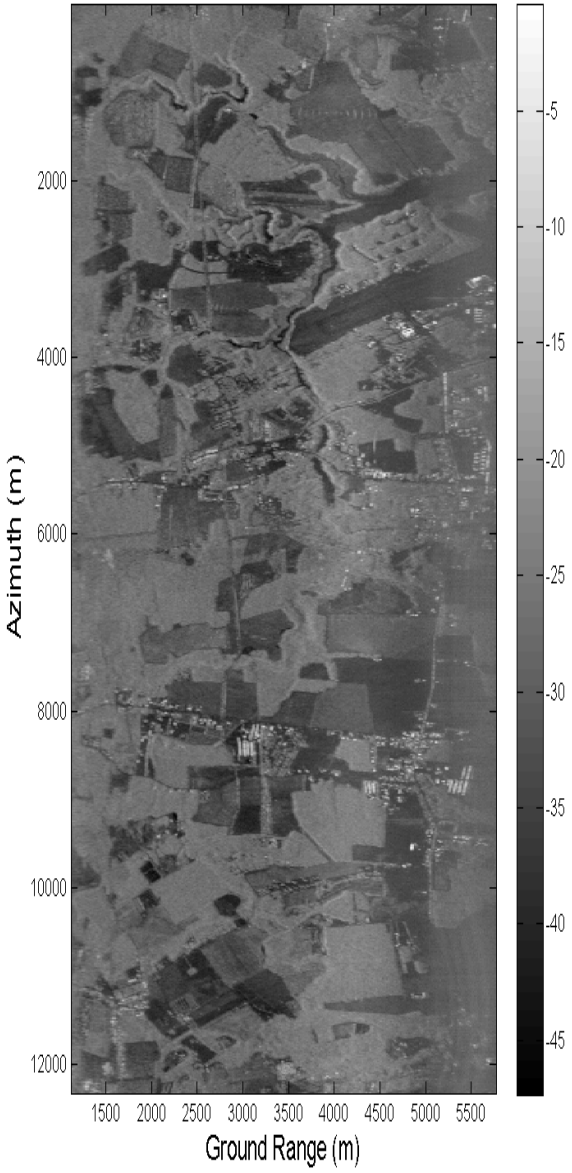


Altimetry

DBSAR Operational Modes

SAR/Narrow Beam

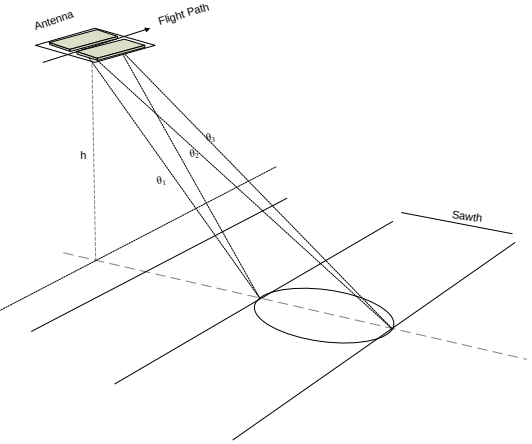


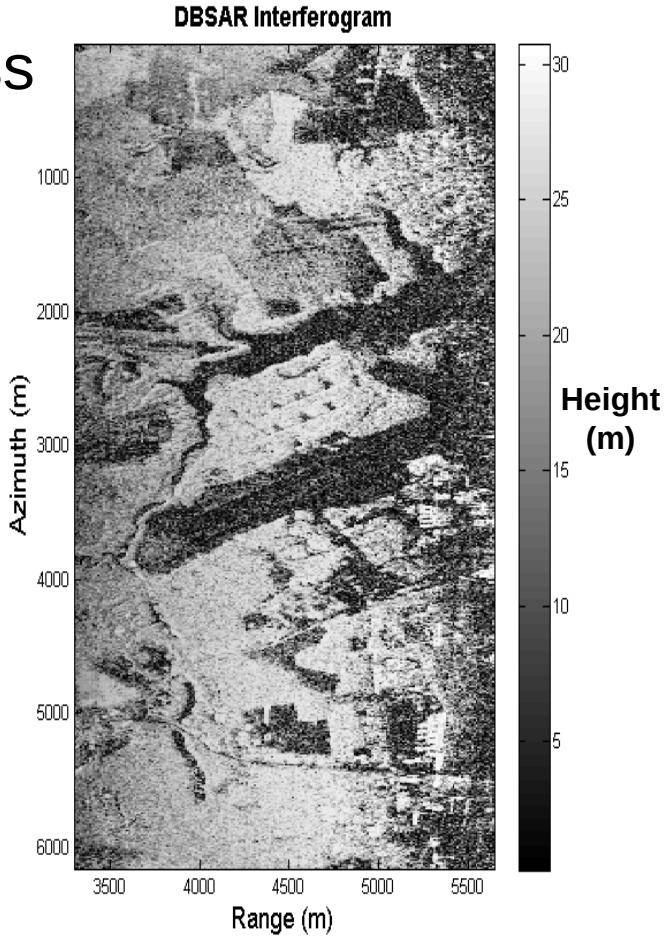


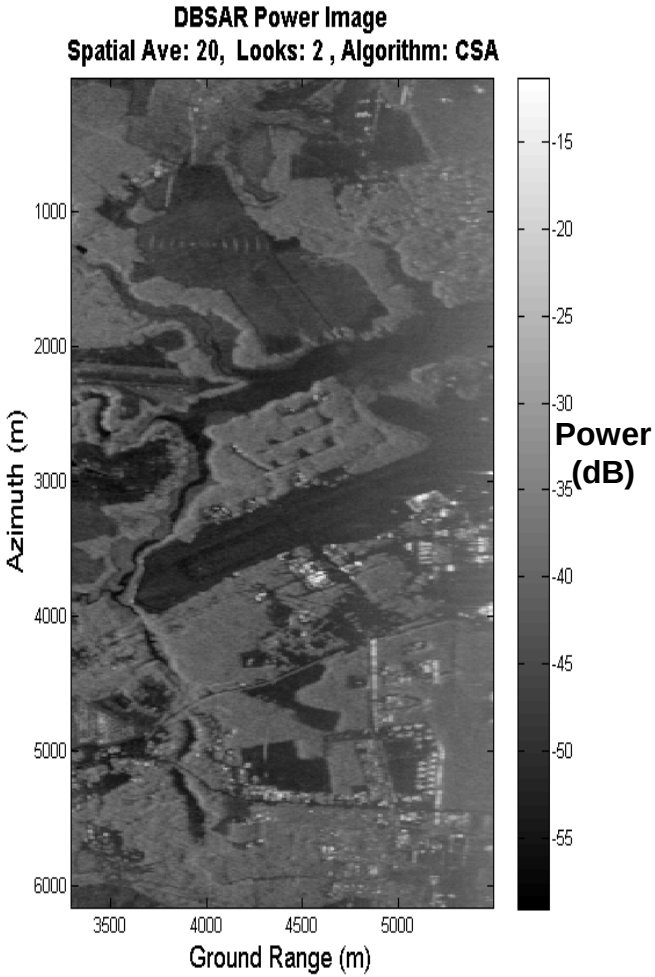
Slant Range Res. = 7.5 m
Azim Res. = 0.5 m (single look)
NESZ ≤ -35 dB (single look)
Aircraft Altitude = 4 km
Aircraft Speed = 150 m/s

DBSAR Operational Modes

InSAR/ Single Pass







DBSAR Operational Modes

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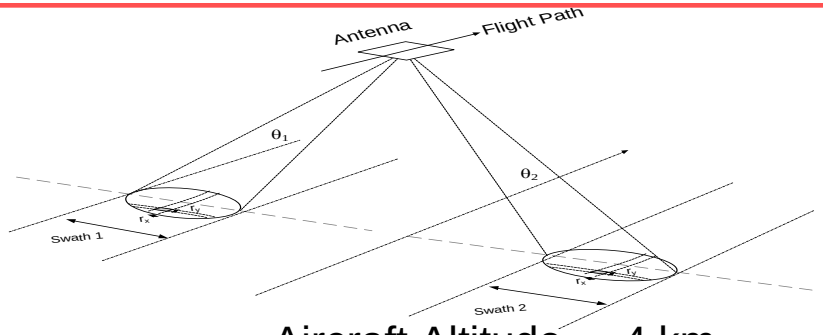
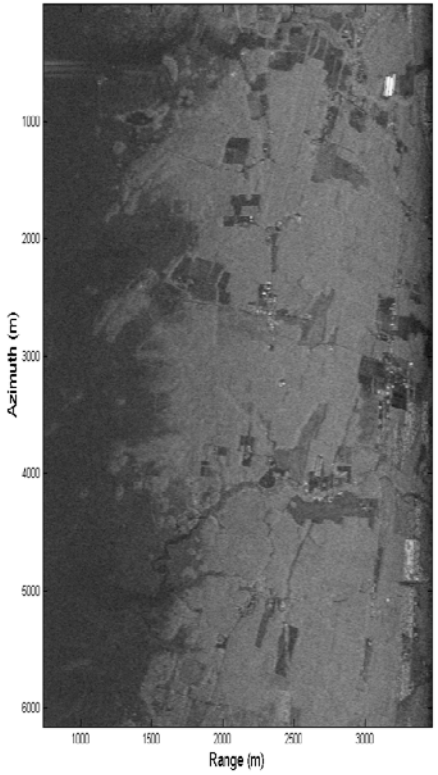
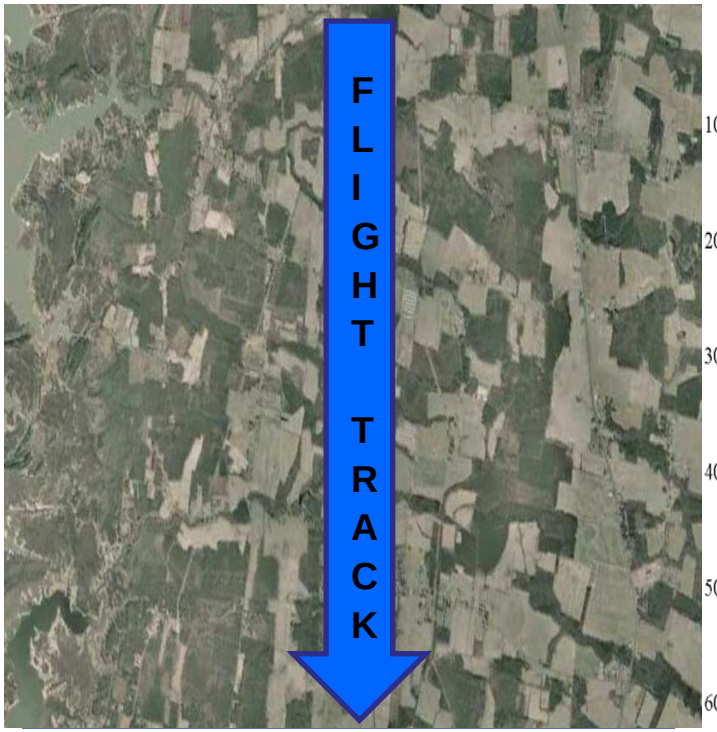
SAR\Wide beam

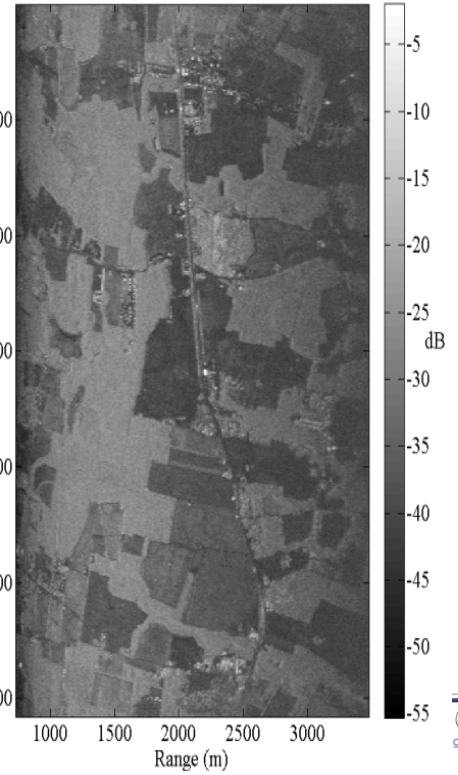


Range Res. = 7.5 m
Azim Res. = 0.5 m (single look)
NESZ ≤ -28 dB (single look)

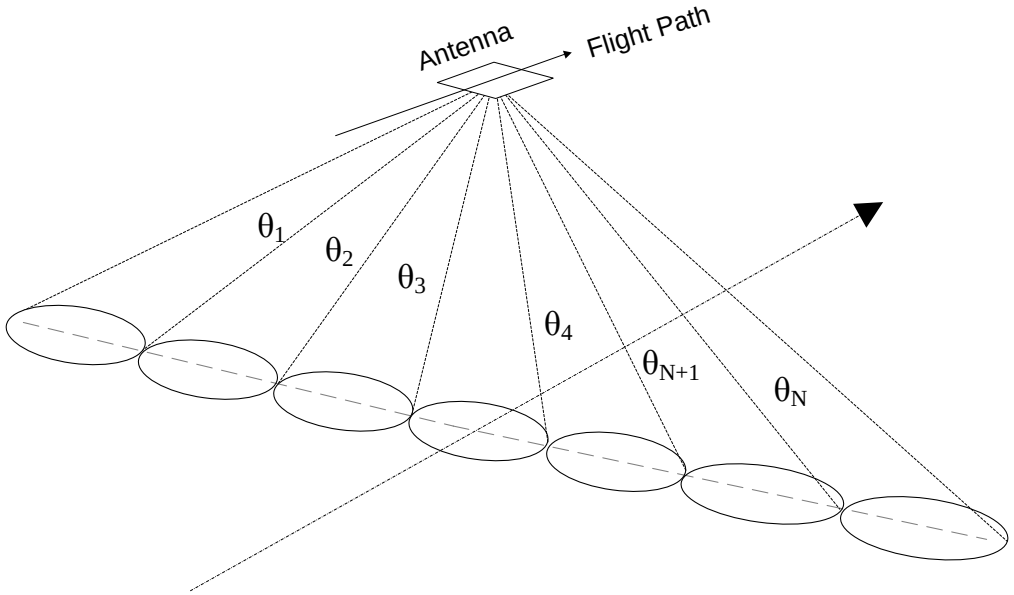
Aircraft Altitude = 4 km
Aircraft Speed = 150 m/s





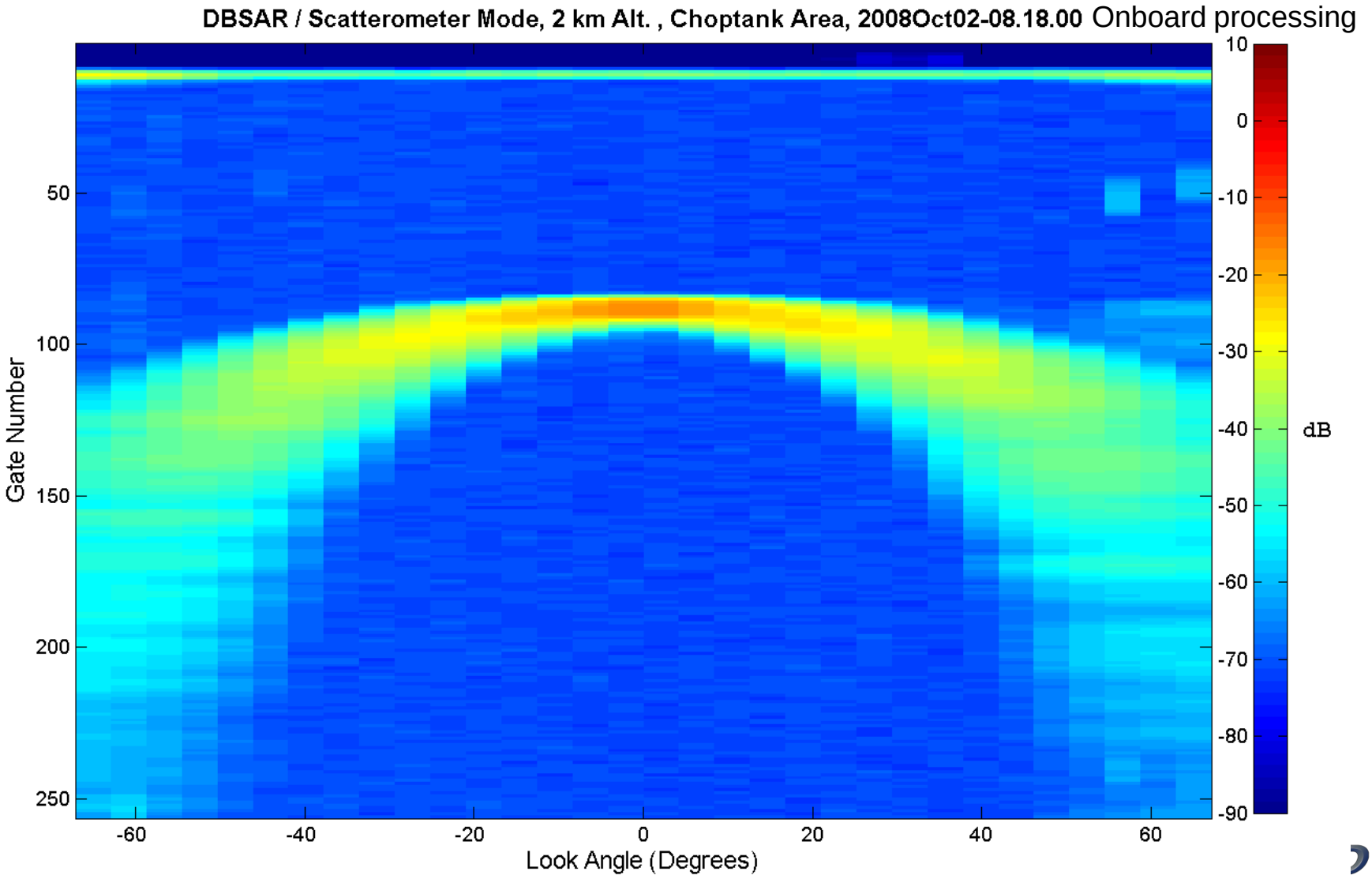


DBSAR Operational Modes

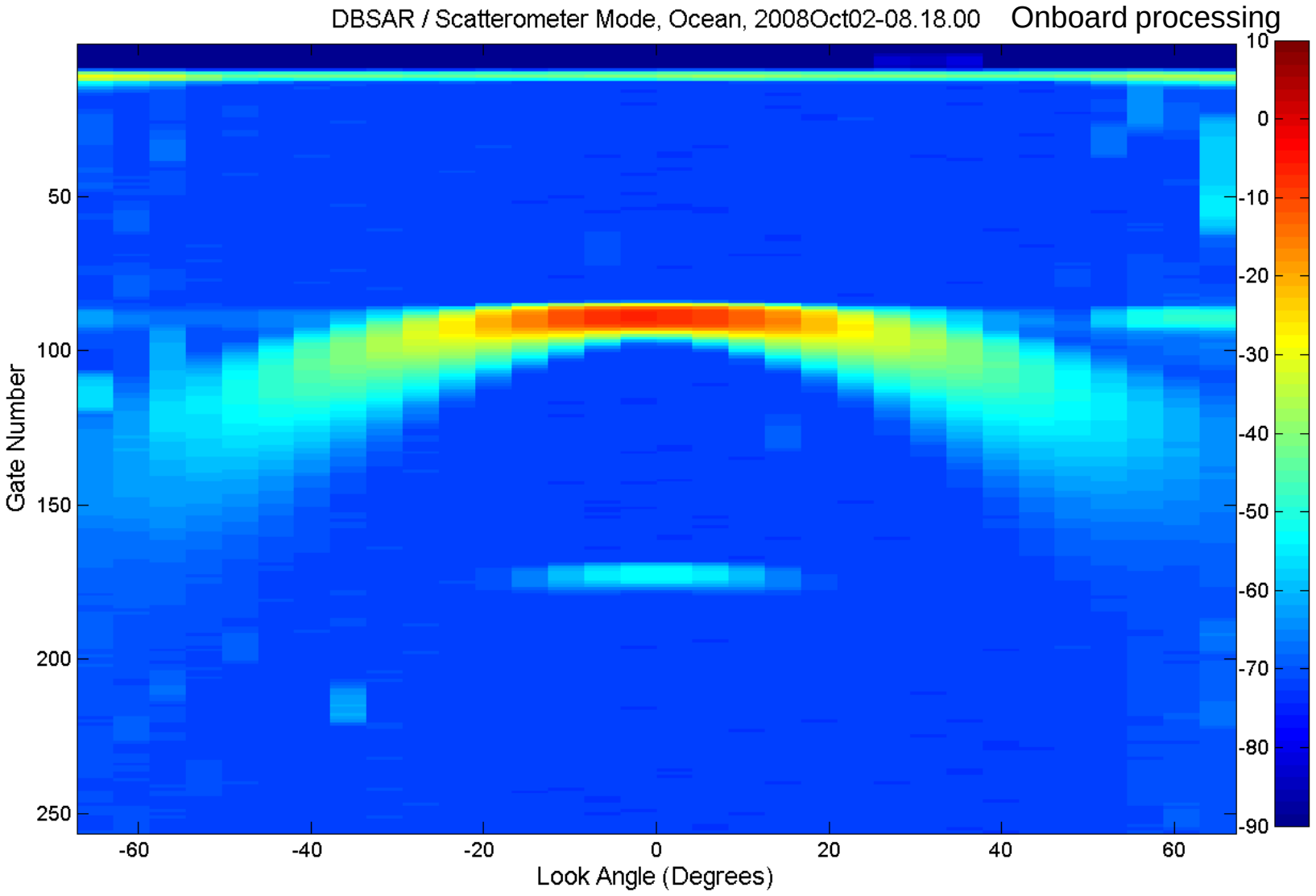


Scatterometry

DBSAR Operational Modes



DBSAR Operational Modes



DBSAR Operational Modes

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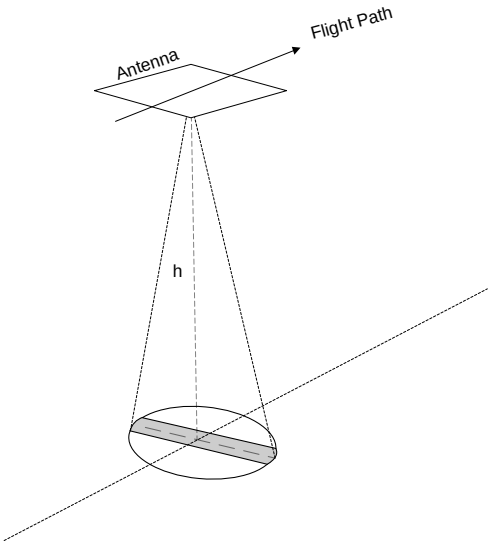
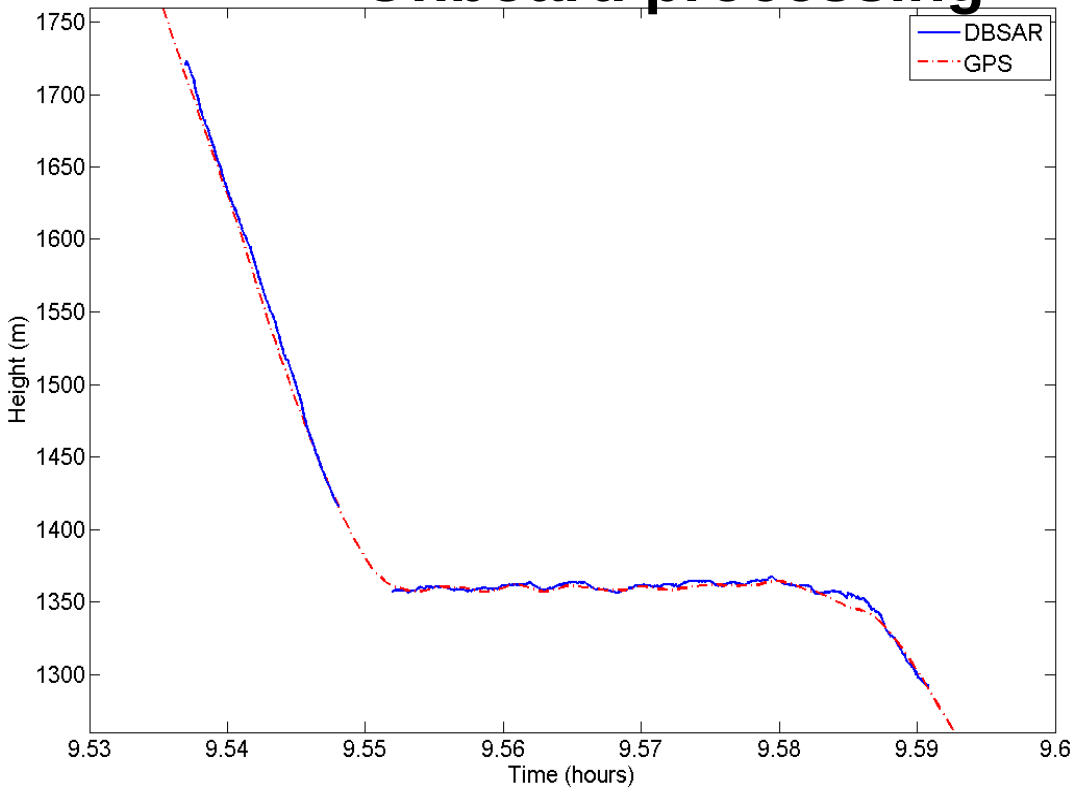
Altimetry



Vertical Resolution 7.5 m

Onboard processing



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DBSAR Polarimetric Upgrade

- The main objective of the upgrade was to enhance DBSAR's capability as a science instrument by adding polarimetric operation. Two polarimetric designs were chosen after considering several design options:

Upgrade 1: Modified the existing radar architecture to enable interleaved polarimetric operation (e.g., sequentially transmit and receive horizontal and vertical polarizations).

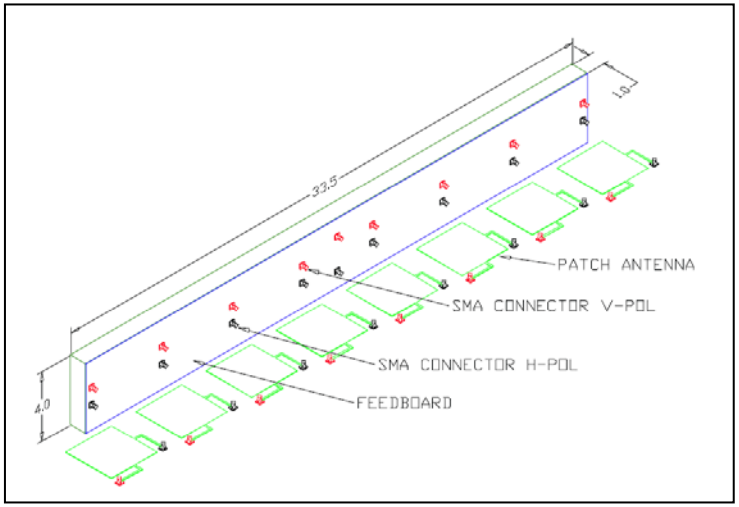
Upgrade 2: Developed new L-band transceivers capable of supporting a full polarization operation (e.g., simultaneously transmit and receive orthogonal polarizations). This approach took a more robust approach in order to fully modernize and miniaturize the system.

DBSAR Polarimetric Upgrade

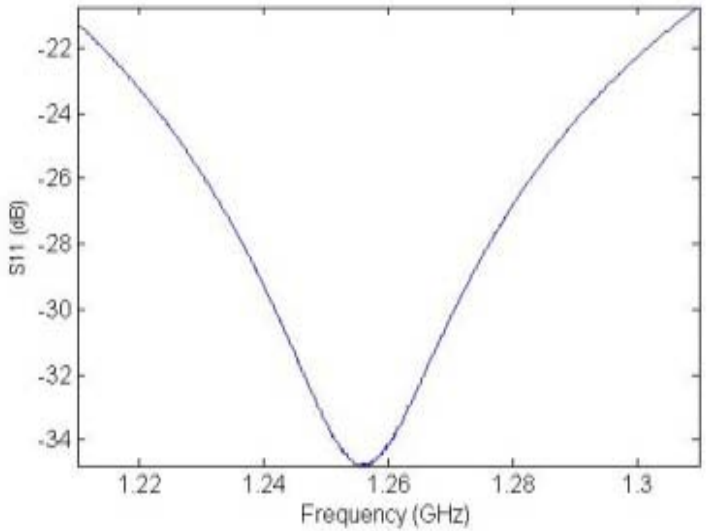
- **Both upgrade approaches required to replace the existing eight antenna feedboards with a new set of dual-channel feedboards.**

Operating Frequency…….	1260 MHz
Bandwidth……	120 MHz @ -15dB return loss
Loss ……	0.4 dB
Fanout ……	8-way with Cosine amplitude taper
	(1-input, 8 outputs for V-pol)
	(1-input, 8 outputs for H-pol)
Size*……	33.5” x 4.0” x 1.0”
Weight ……..	~ 1 lb
Connectors ……..	SMA-F (18ea)

Dual-channel feedboard specifications.



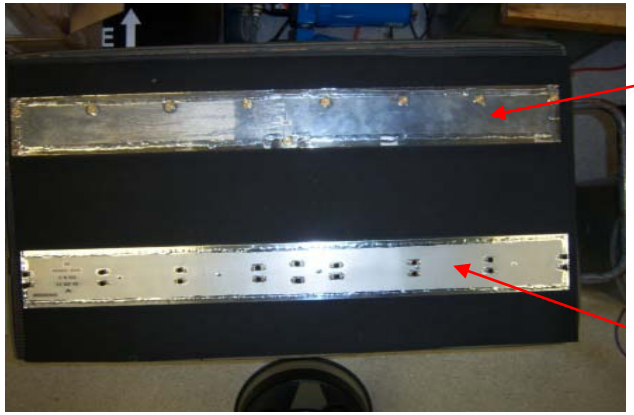
New feedboard design showing its position relative to the DBSAR antenna patches.



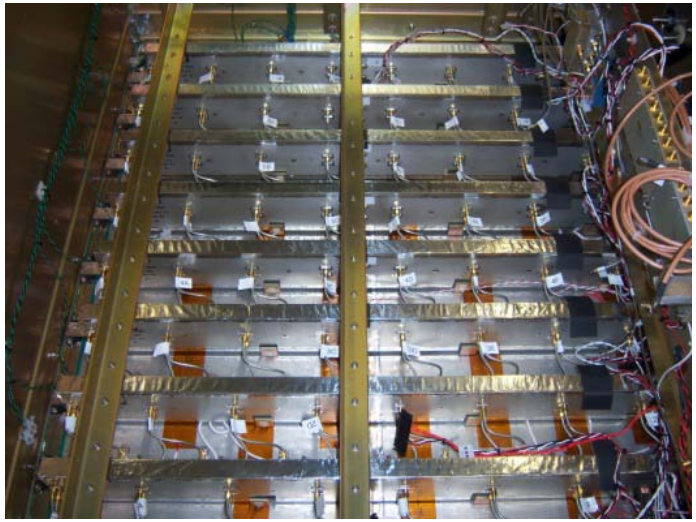
Feedboard return loss

DBSAR Polarimetric Upgrade

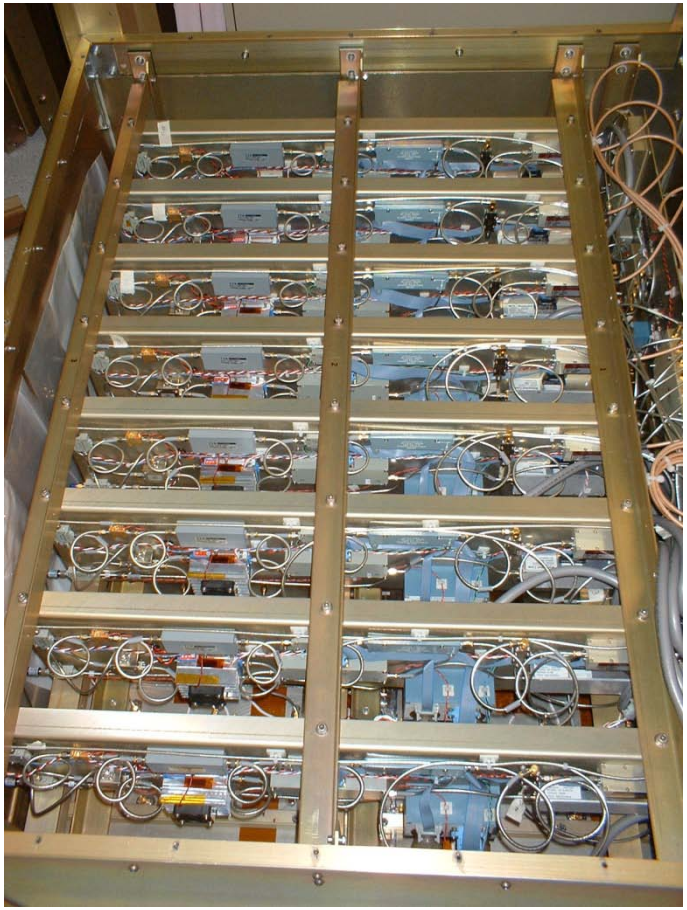
- **Both upgrade approaches** continued .....



Dual-channel feedboards (bottom) replace original single-channel feedboards (top).



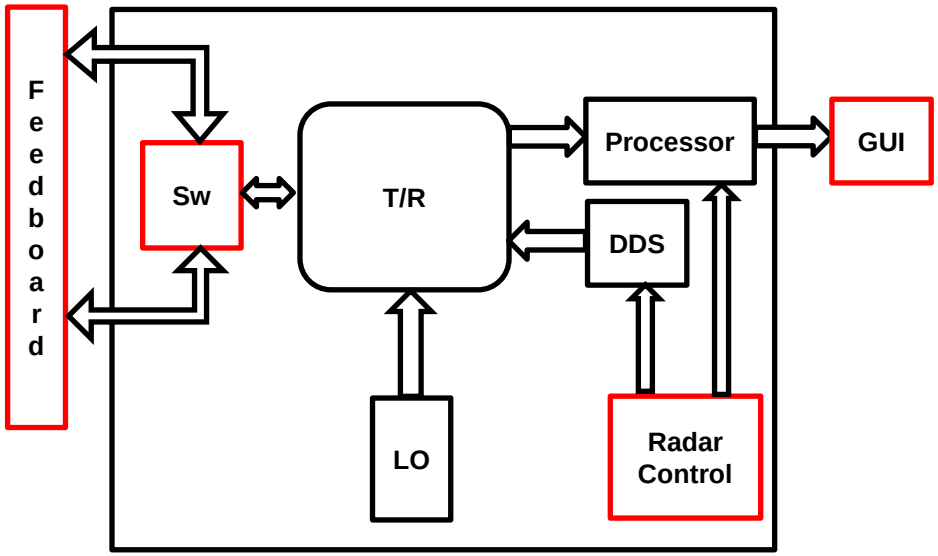
Eight dual-channel feedboards integrated to DBSAR antenna



DBSAR transceivers integrated with feedboard network and antenna

DBSAR Polarimetric Upgrade

- Approach #1 required modifications to hardware, firmware, and software. The main aspects of the upgrade involved:
  - Addition of solid state switches to the existing transceivers
  - Upgrade Radar Control Card logic & timing firmware to support polarimetric measurements
  - Modifications to graphical control unit



DBSAR polarimetric upgrade architecture showing new components (in red). The block diagram shows only one out of the eight transceivers, feedboards, and antenna subarrays.

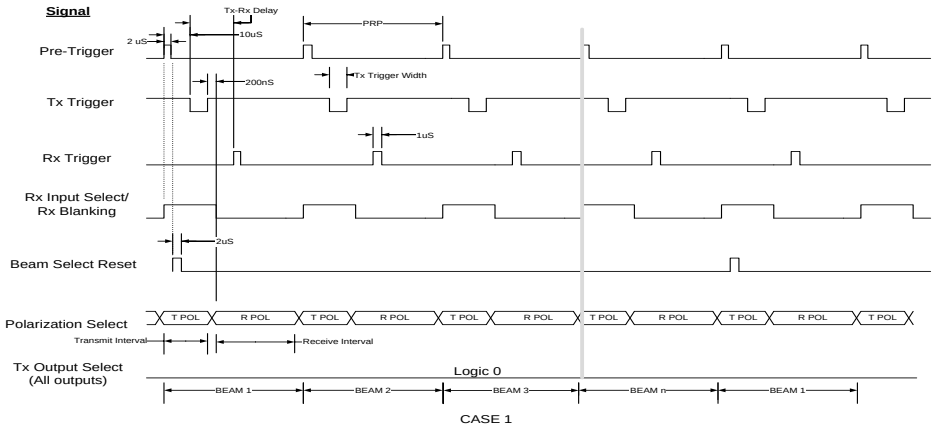
New solid state SPDT switches toggling among selected polarizations.

DBSAR Polarimetric Upgrade

- **Approach #1 task requirements continued…..**

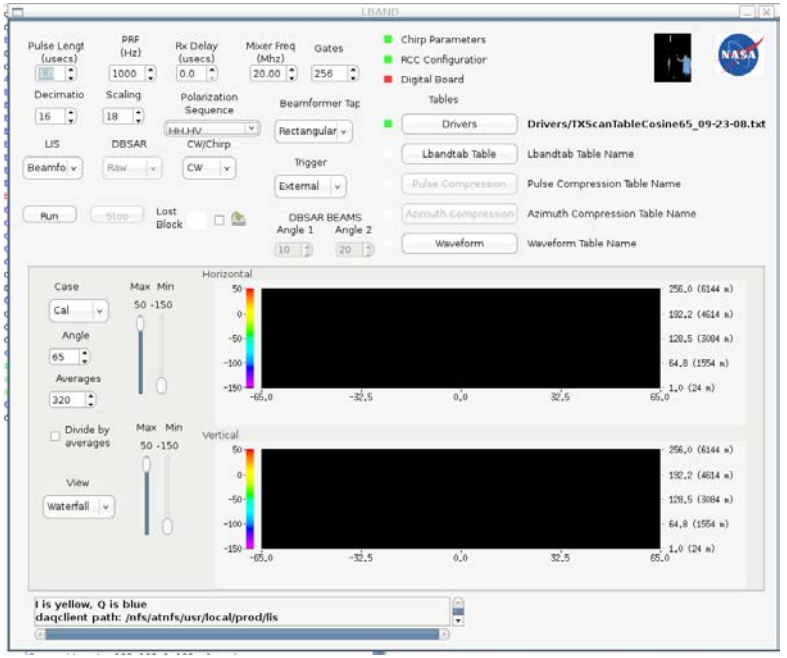
  –Upgrade Radar Control Card logic & timing firmware to support dual-polarimetric measurements

  –Modifications to graphical control unit



Possible Polarization Sequences:
HH
HH,VV
HH, HV
HH, VV, HV
HH, VV, VH, HV

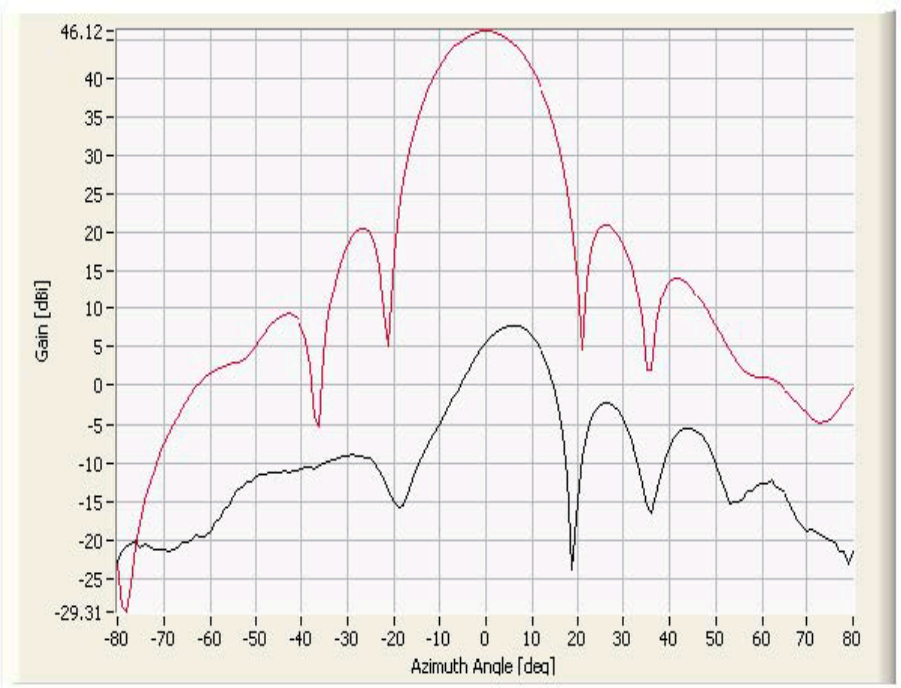
Modifications to the DBSAR Radar Control Card Firmware allows the sequential measurement of selected polarizations.

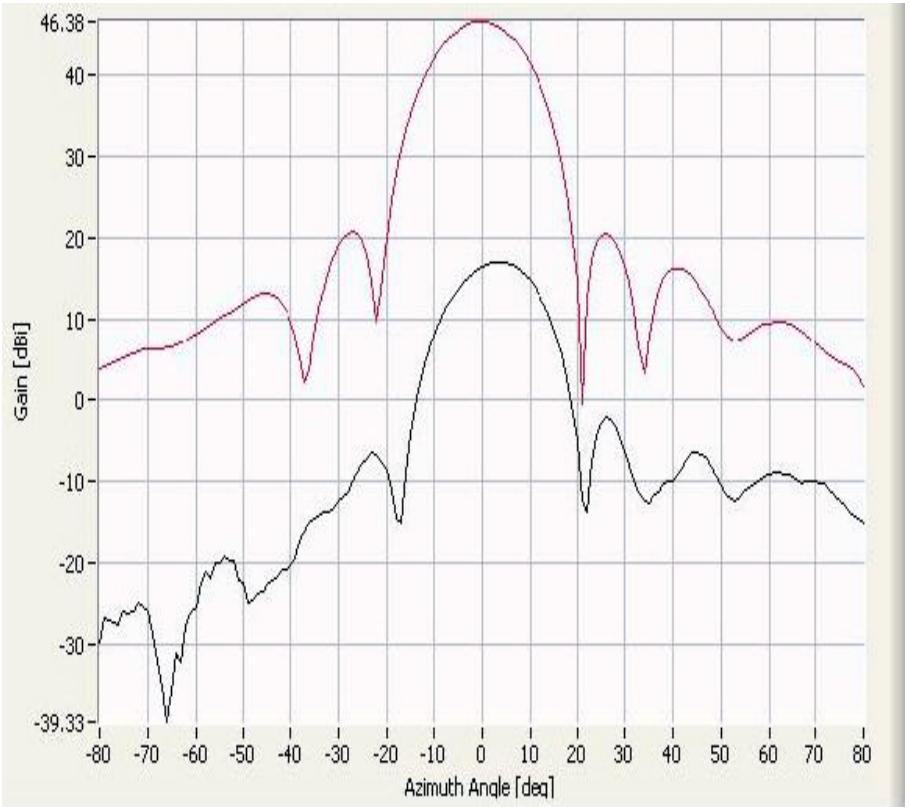


Modifications to the DBSAR GUI allows the configuration of polarimetric modes and the real time display of on board processed data.

DBSAR Polarimetric Upgrade

Approach #1 Anechoic Chamber Calibration and Testing:

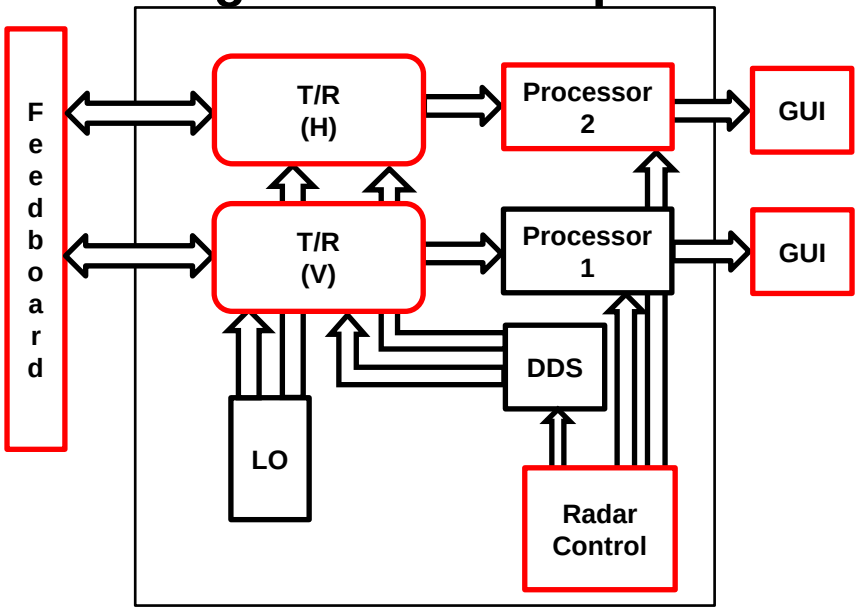




One-way pattern measurements of co-pol and cross-pol signals for horizontal (left) and vertical (right) polarizations.

DBSAR Polarimetric Upgrade

- Upgrade Approach #2 required the development of compact dual-channel transceivers that can enable full polarization operation. The main aspects of this upgrade involved:
  - In-house design of L-band transceivers
  - Build a copy of DBSAR processor for the acquisition and data handling of additional polarizations



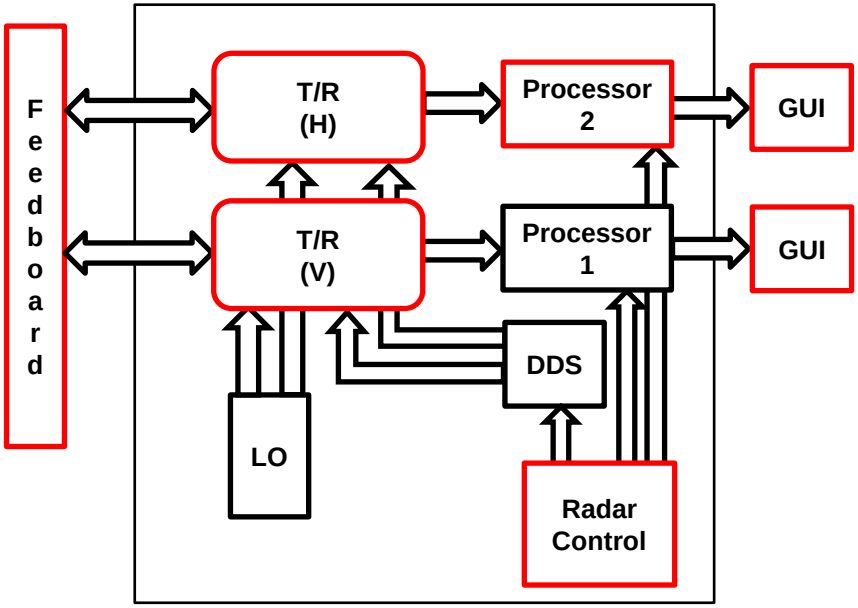
New L-band polarimetric transceiver
(27.5 cm x 9.5 cm x 1.5 cm)

DBSAR polarimetric upgrade architecture showing new components (in red). The block diagram shows only one out of the eight transceivers, feedboards, and antenna subarrays.

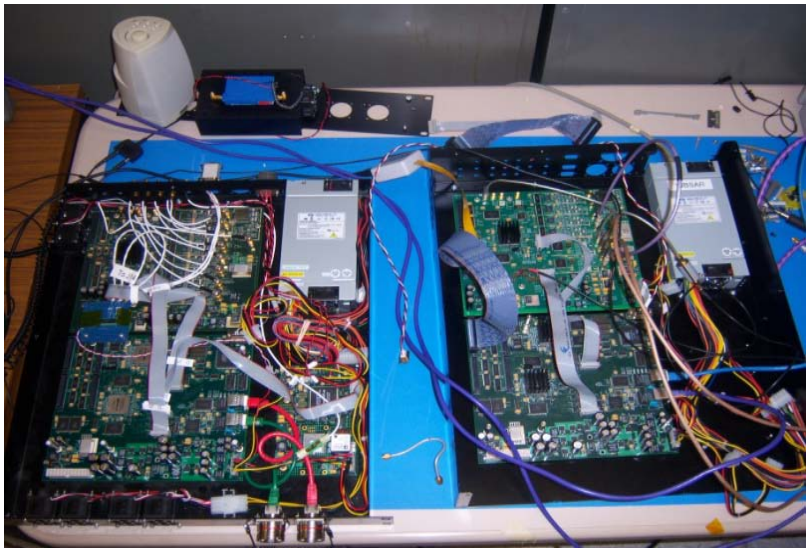
DBSAR Polarimetric Upgrade

- **Approach #2 task requirements continued…..**

  –Build a copy of DBSAR processor for the acquisition and data handling of additional polarizations.



Laboratory testing of hardware required to interface transceivers and enable polarimetric measurements in DBSAR.



Original and new digital processors. The two DBSAR processors can acquire and process the polarization capability in real-time.

Current and Future Efforts

- **The sequential polarimetric capability (approach 1) will be tested in the summer of FY2011 when DBSAR will participate in a science campaign to measure forests biomass and planetary analogs.**

- **Full integration of the new transceivers (approach 2) with DBSAR will be completed in 2011. The upgraded architecture will be fly-tested in FY2012,**

- **Biomass estimates from DBSAR measurements are being conducted in collaboration with the Biosphere Science Branch (Code 614.4) under a FY11 IRAD.**

- **Ocean surface roughness estimates from DBSAR scatterometer measurements are also underway in collaboration with the Ocean Sciences Branch (Code 614.2).**

Backup Slides

Biomass Retrieval Efforts

- Biomass field measurements over DBSAR mapped areas.
- Evaluation of DBSAR, UAVSAR and PALSAR Images over the Delmarva Peninsula.
- Correlation between radar backscatter and ground truth biomass.

Biomass Retrieval Efforts

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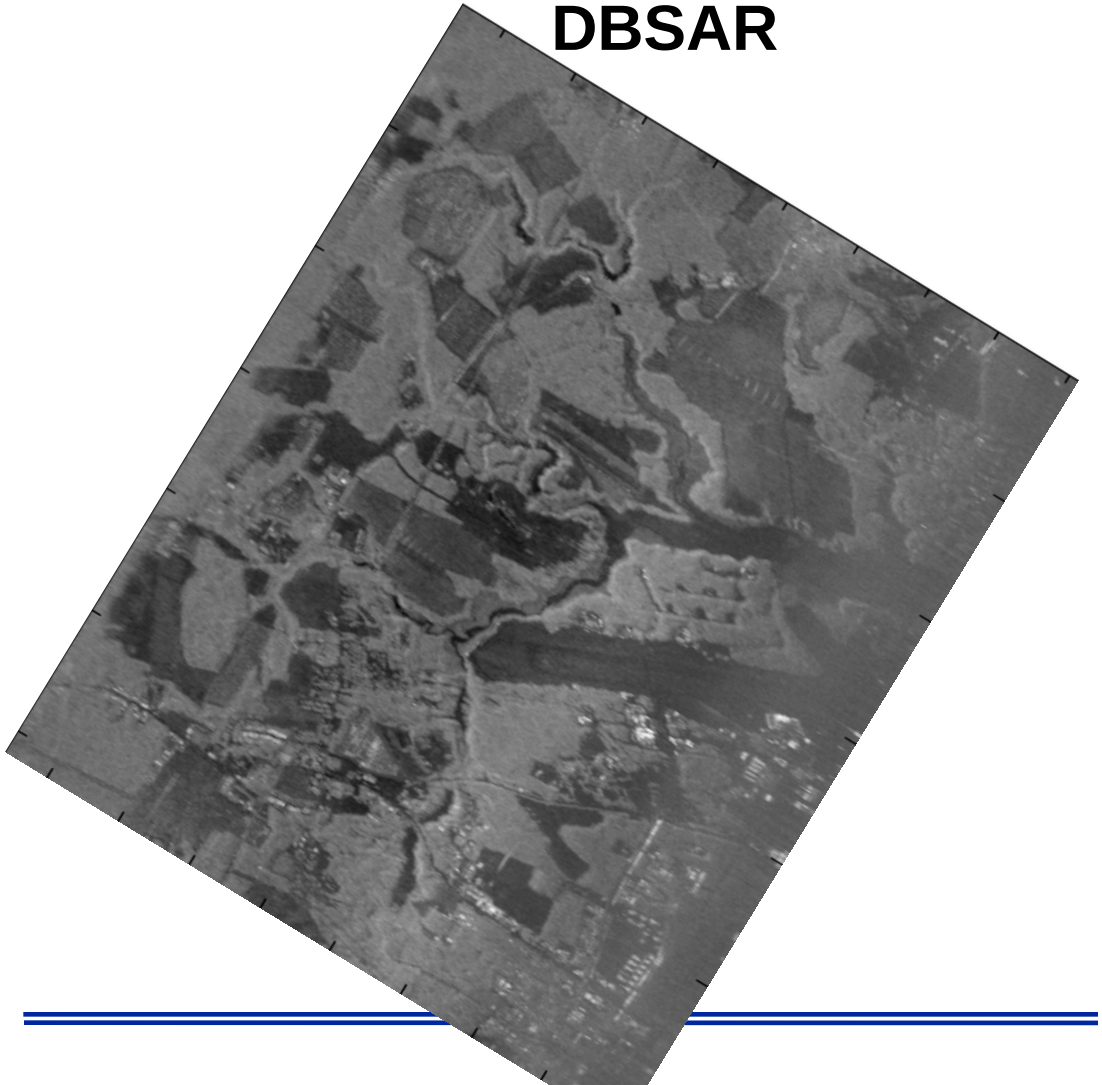
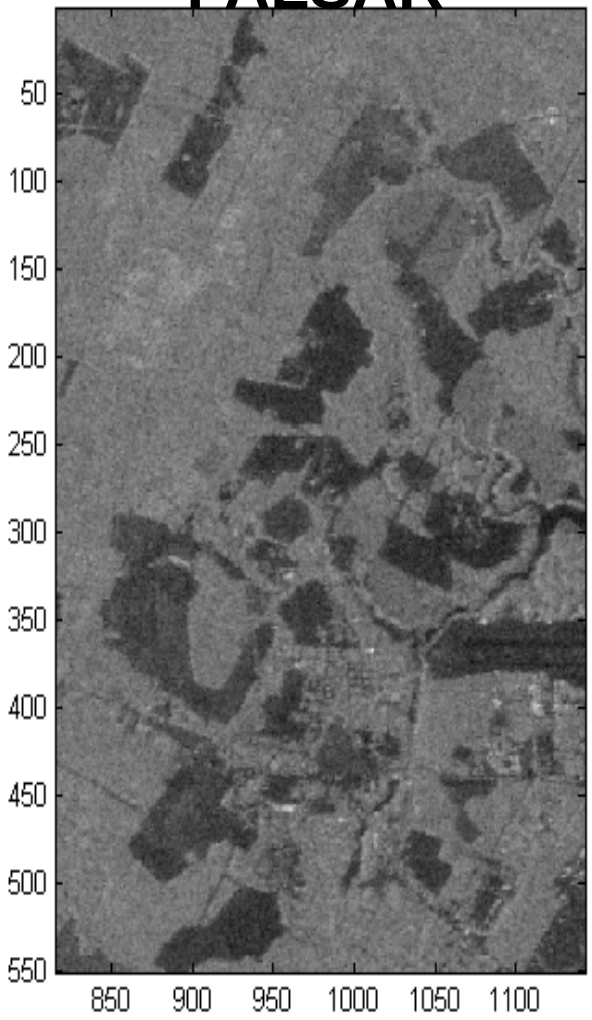
Image calibration and evaluation using PALSAR

DBSAR



PALSAR

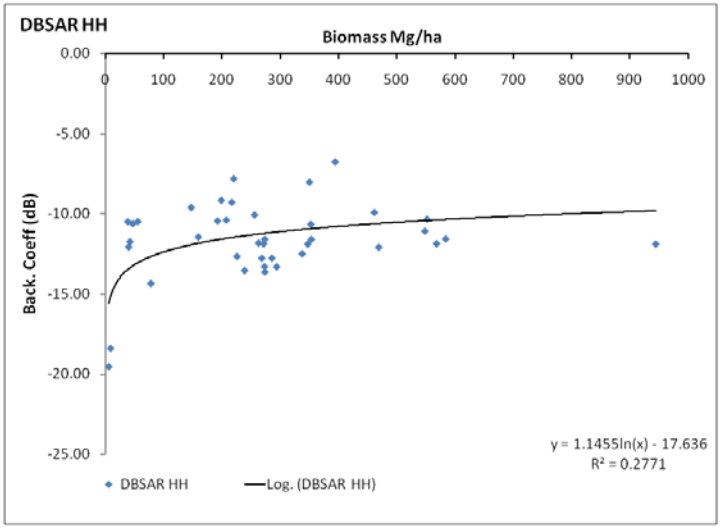


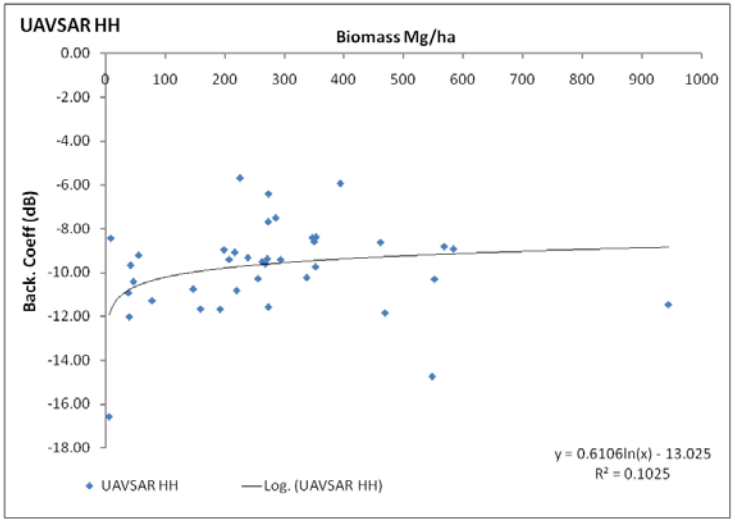
Biomass Retrieval Efforts

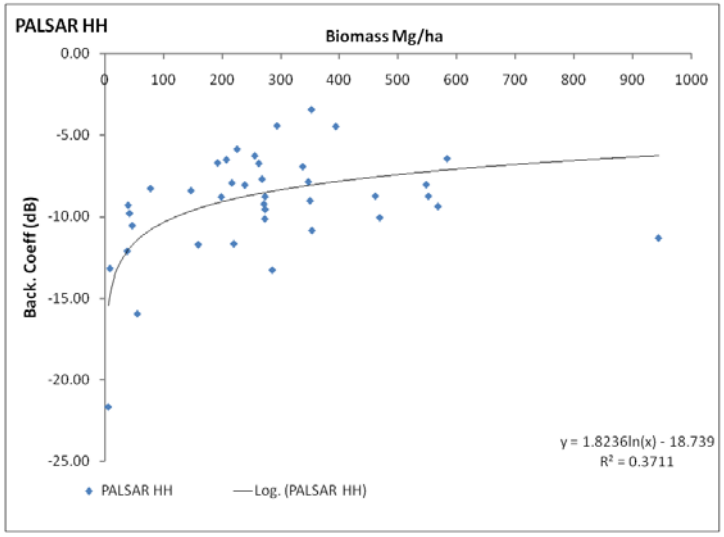
Wallops Biomass Field Measurements

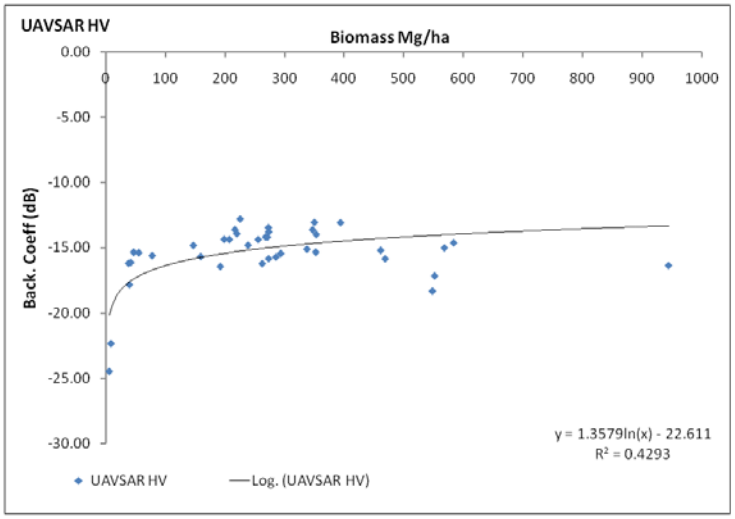
Biomass Retrieval Efforts

Radar Backscatter vs. Biomass

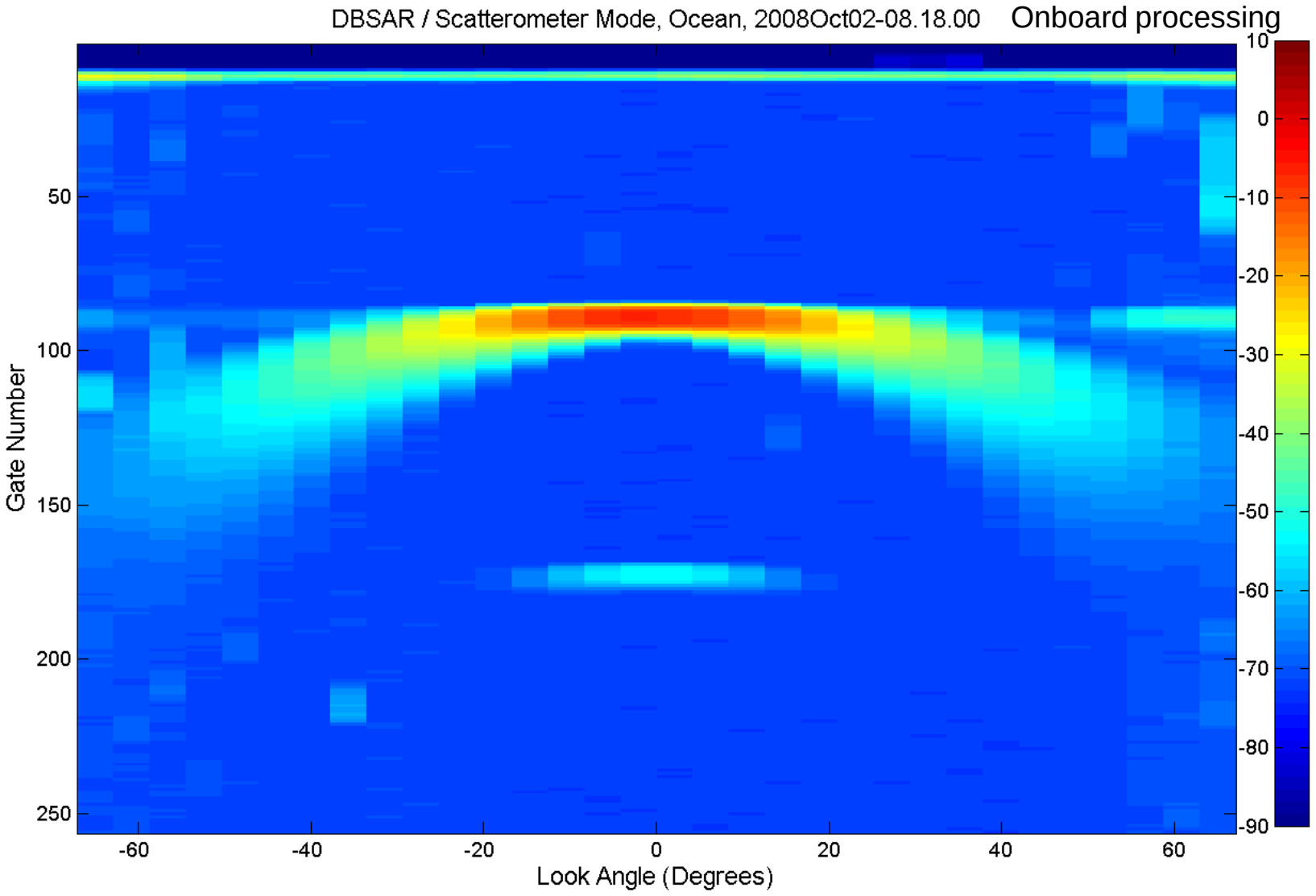








DBSAR Operational Modes



Ocean Surface Retrieval Efforts

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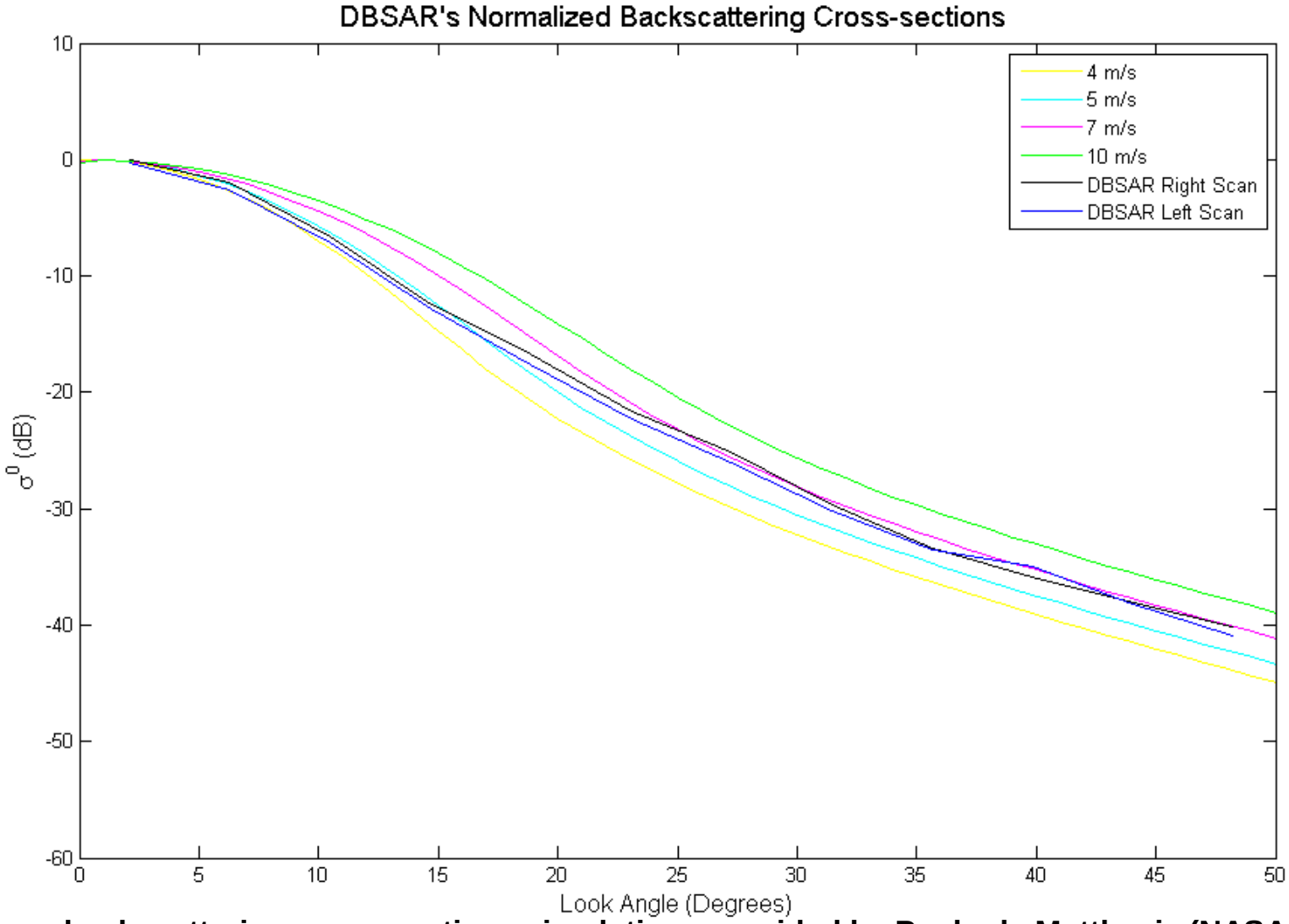

Ocean backscattering cross-sections simulations provided by Paolo de Matthaeis (NASA/GSFC)