Digital Beamforming Synthetic Aperture Radar (DBSAR) Polarimetric Upgrade

Rafael F. Rincon, Martin Perrine, Matthew McLinden, and Susan Valett.
NASA/Goddard Space Flight Center, Greenbelt, MD 20771

Abstract - The Digital Beamforming Synthetic Aperture Radar (DBSAR) is a state-of-the-art radar system developed at NASA/Goddard Space Flight Center for the development and implementation of digital beamforming radar techniques. DBSAR was recently upgraded to polarimetric operation in order to enhance its capability as a science instrument. Two polarimetric approaches were carried out which will be demonstrated in upcoming flight campaigns.

Introduction

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 [1]-[3].

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 operated in single polarization, its architecture was designed with a dual-polarization antenna that could accommodate upgrades to polarimetric operation.

DBSAR’s upgrade to polarimetric operation was recently accomplished through an Earth Science Technology Office (ESTO) award aimed at enhancing DBSAR’s capability as a science instrument. The polarimetric operation will provide information about the scattering mechanism of reflecting media which can be used to determine their properties and characteristics. Examples of media with polarimetric signatures to be measured with DBSAR include forests, agricultural areas, and ocean surface. These measurements are important for scientific research and play a critical role in future airborne and spaceborne radar missions.

DBSAR's polarimetric upgrade was implemented using two design approaches. The first approach modified DBSAR's existing single polarization architecture to enable interleaved polarimetric operation (e.g., sequentially transmit and receive horizontal and vertical polarizations). This option did not provide a full polarimetric capability but it was low risky, low cost, made use of a proven architecture, and provided all radar polarizations in a sequential manner. The second approach developed new L-band transceiver modules that enable a full polarimetric operation (e.g., simultaneously transmit and receive orthogonal polarizations).

Background

DBSAR evolved from early GSFC IRAD efforts aimed at the development of the RADSTAR, an active/passive spaceborne system concept that combined an L-band imagining scatterometer and a Synthetic Thinned-Array Radiometer (STAR) for the measurement of soil moisture and ocean salinity [4]. Since then, DBSAR evolved to include state-of-the-art features such as reconfigurable hardware and firmware, a multi-channel data acquisition and real time processor system, reconfigurable waveform generation, and a high resolution navigation system. Table I summarizes current DBSAR's parameters and characteristics.

TABLE I
DBSAR's Upgraded electrical characteristics

Center Frequency	1.26 GHz (L-band)
PRF max	10 kHz
Pulse Width	1 to 100 µs
Maximum Bandwidth	20 MHz
Polarization	HH, HV, VH, VV
Slant Range Resolution	7.5 m
Maximum Output Power	16 W
Beam Steering Angles	> ±50 degrees
Intermediate Frequency	20 MHz
Antenna Type	Microstrip Patch Array
Antenna Size	1.2 m x 1 m
Number of Active Subarrays	8
Subarray Gain	12.5 dB
Subarray 3-dB Beamwidth	106 degrees

DBSAR's first multi-mode campaign took place in the fall of 2008 onboard the NASA P-3 aircraft (Fig. 1) over areas of the Delmarva Peninsula and Virginia. The flights covered areas that included ocean, agricultural and forested land, coastal marshes, and the Chesapeake Bay at altitudes ranging from 2 km to 8 km. Speeds were maintained at approximately 150 m/s. Over 13 hours of horizontal polarization (HH) data were collected using multi- mode techniques [3].

Fig. 1. DBSAR integrated to the NASA P3 aircraft

Modes implemented with DBSAR include several variations of synthetic aperture radar (SAR), Interferometric SAR (InSAR), scatterometry over multiple beams, and altimetry [3]. SAR and single pass InSAR Images collected during the 2008 flight campaign are shown in Figure 2.

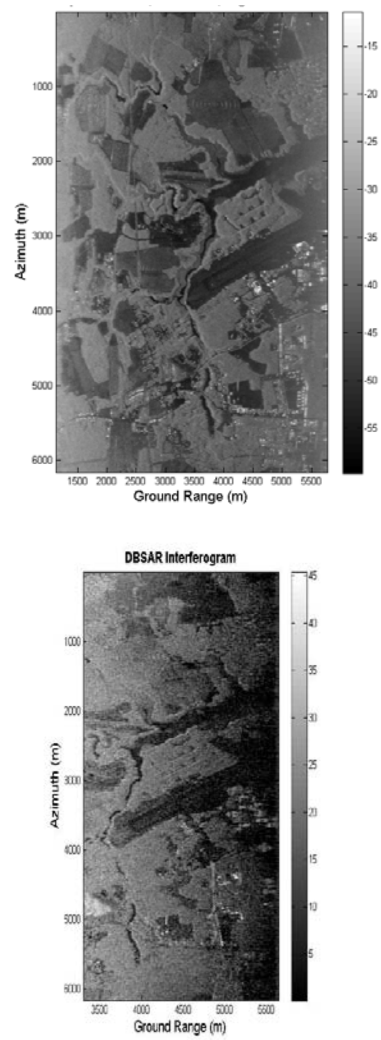

Fig. 2. Single polarization SAR (top) and single pass InSAR (bottom) images of the Wallops Flight Facility, VA generated from a 4 km altitude

System Upgrades

The main objective of the upgrade was to enhance DBSAR's capability as a science instrument by adding polarimetric operation and thus enabling the measurement of the full radar backscattering matrix.

The two design approaches chosen for polarimetric operation required new dual polarity antenna feeds. As noted earlier, DBSAR's was originally designed with a dual-polarization antenna, however, the antenna feeds employed in the original design supported one polarization. Consequently, ten dual-polarity feedboards were developed for this purpose. Figure 3 shows the new feedboards integrated to the DBSAR array antenna (antenna is facing down), and the return-loss for one of the feedboards. Laboratory measurements showed that all feedboards had nearly identical performance.

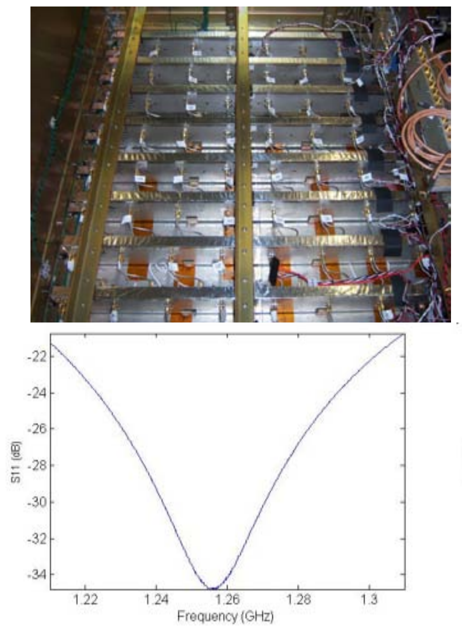

Figure 3 DBSAR's dual polarity feedboards integrated to the DBSAR antenna (top) and single feedboard return-loss (bottom).

The first approach made use of the existing single channel transceivers. The upgrade added solid state switches between the transceivers and the antenna feedboards to allow the selection of the horizontal or vertical transmit and receive operation. The radar's software and firmware were updated to support the polarimetric operation. Figure 4 shows several of the new switches installed on the radar transceivers.

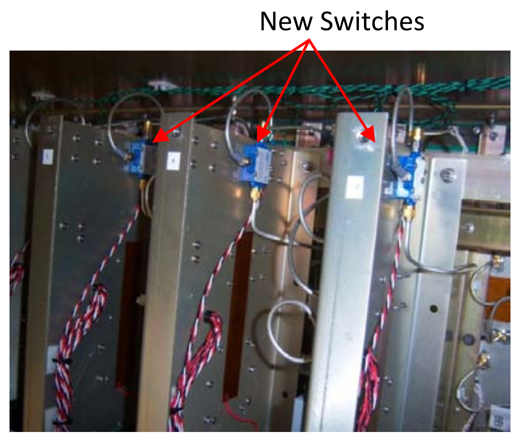

Fig. 4. New switches between transceivers and antenna feedboards enable DBSAR's polarimetric operation.

Upon completion of the first upgrade approach, DBSAR was fully tested in the laboratory, and later calibrated at NASA\GSFC anechoic chamber in preparation for the August 2011 flight campaign. Figure 5 shows co-polarity (red trace) and cross-polarity (black trace) boresight antenna patters measurements. The patterns shown were electronically beamformed with a cosine taper illumination.

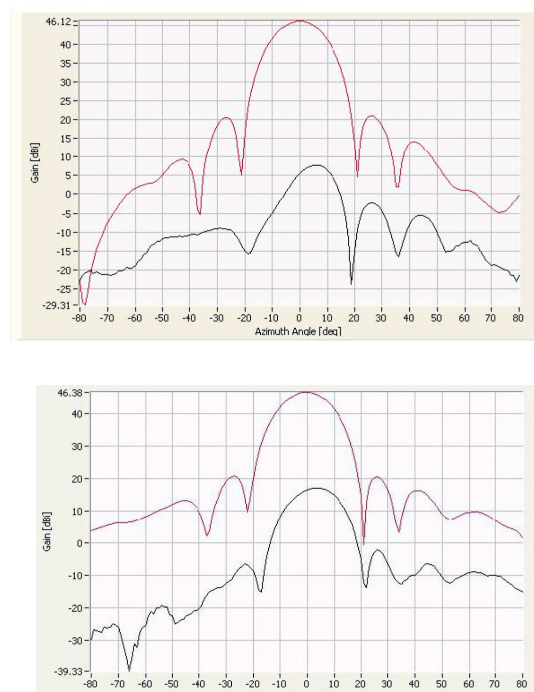

Fig. 5. Anechoic measurements of DBSAR transmit pattern measurements of co-pol and cross-pol signals for horizontal (top) and vertical (bottom) polarizations.

The second approach developed new transceivers capable of supporting a full polarization operation. This upgrade took a more robust approach in order to fully modernize and miniaturize the system. The new transceivers were designed on printed circuit boards and used surface mount miniature components, reducing the size by a factor 4 while exhibiting an RF performance similar to the original transceivers. Six transceiver units has been constructed and are currently being tested in the laboratory.

Figure 6 shows one of the 16 transceiver modules required for DBSAR's full polarimetric operation. A pair of modules makes up one DBSAR channel.

Fig. 6 DBSAR polarimetric Transceiver Module

Full integration of the new transceivers with the DBSAR architecture is currently under way through a GSFC IRAD award. The fully polarimetric upgrade will be demonstrated in future flight campaigns.

Conclusion

The two polarimetric upgrades carried out under this effort will provide more accurate estimates of important scientific parameters such as biomass and surface roughness.

The new sequential polarimetric capability will be demonstrated in the summer of 2011 when DBSAR will participate in a flight campaign to measure forests biomass.

The new fully polarimetric transceivers are currently being tested in the laboratory and will be demonstrated in 2011/2012 as the DBSAR flies future science campaigns.

Implementation of the two upgrade approaches will allow validation, and calibration of the polarimetric measurements during science campaigns later in 2011 and 2012.

Acknowledgement

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References

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