

RADARSAT-2: Program Overview and Applications

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Abstract: The RADARSAT-2 program is an excellent example of public-private partnerships joining forces to, in this case, commercialize a spaceborne SAR program. The advanced features of RADARSAT-2 will keep Canada in the forefront of spaceborne SAR by providing end-users and researchers with access to high resolution, multi-polarized SAR data, supported by an efficient ground segment designed to deliver data in a timely manner. It is projected that the advanced features of RADARSAT-2 will open-up new applications for SAR-derived information, in addition to providing continuity for well-established RADARSAT-1 applications such as ice mapping and maritime surveillance.

Key Words: RADARSAT-2, radar remote sensing, radar applications

1.0 Introduction

RADARSAT-2, the second in a series of Canadian spaceborne Synthetic Aperture Radar (SAR) satellites, is being built by MacDonald Dettwiler, Richmond, Canada. RADARSAT-2, jointly funded by the Canadian Space Agency and MacDonald Dettwiler, is a good example of public-private partnerships. RADARSAT-2 builds on the heritage of the RADARSAT-1 SAR satellite, which was launched in November 1995 (Srivastava *et al.*, 2001). RADARSAT-2 will carry an advanced single-sensor polarimetric C-band SAR (5.405 GHz). RADARSAT-2 is scheduled for launch in late 2005 from Vandenberg Air Force Base, California.

RADARSAT-2 retains the same capability as RADARSAT-1 (Morena *et al.*, 2004). For example, the RADARSAT-2 orbit parameters will be the same as those of RADARSAT-1, thus allowing co-registration of RADARSAT-1 and RADARSAT-2 images. Radiometric and geometric calibration will also be implemented, permitting the correlation of time series data for applications such as long-term change detection (Luscombe, 2004). Key features of the RADARSAT-2 satellite include:

- 3 m high resolution
- Fully-polarimetric modes
- Enhanced ground system
- Routine left and right looking capability
- Increased geometric accuracy
- On-board solid state recorders

RADARSAT-2 mission requirements were designed to meet the needs of current RADARSAT-1 commercial interests, and to provide advanced SAR imaging to open-up new applications for the provision of data and information. A critical component to ensure continuity of RADARSAT-1 applications and the development of new RADARSAT-2 applications is the commercialization process. The commercialization process is lead by RADARSAT International (RSI), a MDA company, in partnership with a worldwide network of distributors, strategic partners, and ground receiving stations.

2.0 RADARSAT-2 Features and Benefits

Table 1 outlines the features of the RADARSAT-2 system, based on the current MDA design, which are thought to be the most significant in terms of their impact on existing and new applications. These features are incremental relative to RADARSAT-1, so RADARSAT-1 features are not explicitly stated here. For example, the ScanSAR beam modes of RADARSAT-1 represented a significant advancement, but for RADARSAT-2, the ScanSAR beam modes represent the continuity of a feature rather than a new one. Similarly, calibration, which was an integral component of the RADARSAT-1 mission, is also planned for RADARSAT-2.

Table 1. RADARSAT-2 features and benefits

<i>RADARSAT-2 Feature</i>	<i>Benefit</i>
Finer resolution	Improved object detection and recognition will enable a variety of new applications including defense surveillance and mapping at scales of 1:20,000.
Range of resolutions, swaths and incident angles	Programmability of resolution and image swath width address a broad range of applications and provide operational flexibility.
Three polarization modes	Addition of extra polarization modes will enable better discrimination and recognition of objects on the ground, and improved classification capability. Polarization modes will enable RADARSAT-2 to better compete with multispectral sensors.
12-24 hours programming lead time for routine requests, 4-12 hours for emergency requests	A greatly enhanced ability to rapidly program the satellite will ensure RADARSAT-2 will be the system of choice for Defense and Emergency Management clients needing fast access to imagery.
Increased revisit times	Improved monitoring efficiencies will attract operational clients who need high frequency revisits to regions of interest.
Fast processing and delivery	Processing in as fast a timeline as 30 minutes will complement RADARSAT-2's other operational features (programming, revisit, etc.) and further enhance the operational solutions provided to monitoring, defense and emergency management clients.
Increased geometric accuracy	Improved geometric accuracy, particularly without control points, will provide an improved operational monitoring solution for clients requiring fast access to accurately positioned products.
Solid state recorder	The large-capacity and reliable solid state recorder will increase operational flexibility and guarantee images can be acquired anywhere in the world for subsequent down-linking.

3.0 Flexible Polarimetric Imaging Modes

The hallmark of the RADARSAT program has been the availability of user-selectable imaging modes. These modes offer a variety of incidence angles and resolutions that can be optimized to meet application-specific needs (Table 2). Of note are the variable polarization modes, namely Selective Polarization, Polarimetry (also called quad-polarized), and Selective Single Polarization. From a polarimetric perspective, the Selective Polarization and Selective Single Polarization modes provide radar amplitude data in the form of horizontal and vertical orientations defined with-respect-to the Earth's surface: horizontal is parallel and vertical is perpendicular.

Table 2. RADARSAT-2 beam modes

Beam Mode		Approximate Incidence Angle	Nominal Swath Width (km)	Approximate Resolution (m) (Rg x Az)	Number of looks (Rg x Az)
Selective Polarization					
Option 1: Transmit H Receive H and V	Fine	37° - 49°	50	10 x 9	1 x 1
	Standard	20° - 49°	100	25 x 28	1 x 4
	Wide	20° - 45°	150	25 x 28	1 x 4
	ScanSAR Narrow	20° - 46°	300	50 x 50	2 x 2
	ScanSAR Wide	20° - 49°	500	100 x 100	4 x 4
Option 2: Transmit V Receive H and V					
Selective Polarization					
Transmit H Receive H	Low Incidence	10° - 23°	170	40 x 28	1 x 4
	High Incidence	50° - 60°	70	20 x 28	1 x 4
Polarimetry					
Transmit H Receive H and V -then Transmit V Receive H and V	Fine Quad-Pol	20° - 41°	25	11 x 9	1 x 1
	Standard Quad-Pol	20° - 41°	25	25 x 28	1 x 4
Selective Single Polarization					
Option 1: Transmit H Receive H or V	Ultra-Fine	30° - 40°	20	3 x 3	1 x 1
	Multi-Look Fine	30° - 50°	50	11 x 9	2 x 2
Option 2: Transmit V Receive H or V					

Radar polarimetry, that is the amplitude and inter-channel phase data, entails the use of the RADARSAT-2 quad-polarized mode. This mode is unique to RADARSAT-2 and in fact the first commercialization spaceborne SAR sensor to offer quad-polarized data. Access to quad-polarized data, in contrast to amplitude-only radar data, permits considerably more information to be extracted that is germane to the scattering properties of a given target. Figure 1 shows a quad-polarized SAR image acquired by the Canadian CV-580 airborne SAR. Quad-polarized data includes four amplitude channels and the phase information. The amplitude channels are termed HH, HV, VH, and VV, where HH

implies the horizontal send/receive orientation, VV the vertical send/receive orientation, HV the horizontal send, vertical receive orientation, and VH the opposite of HV. Note that in most cases $HV = VH$.

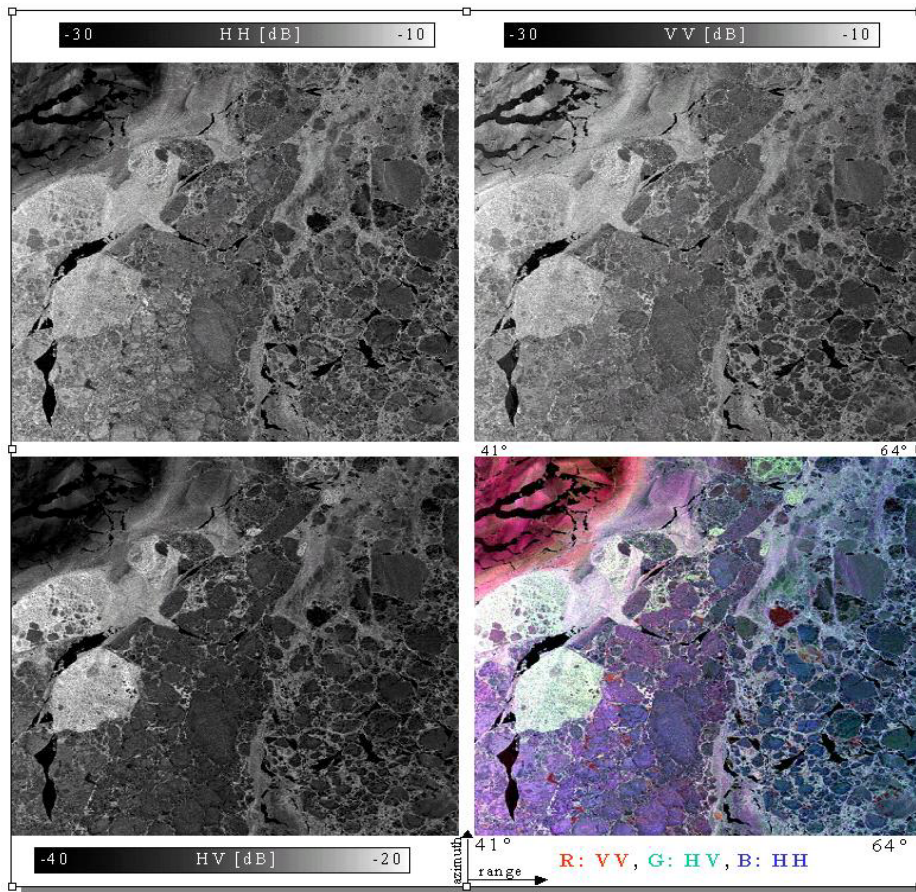


Figure 1. CV-580 airborne SAR image showing ice off the east coast of Canada. Note the differences in the HH, VV, and HV images, notably in the upper left-hand corner. The image in the lower right-hand corner is a merge of HH+VV+HV (Scheuchl *et al.*, 2001).

4.0 Advanced Capability

In addition to the polarimetric capability of RADARSAT-2, a number of advanced features have been incorporated into the satellite design. These features include the moving object detection mode and the SpotLight mode.

Moving Object Detection Mode

RADARSAT-2 will have an experimental research mode used to demonstrate spaceborne detection of moving targets. This mode, called the Moving Object Detection Experiment (MODEX) mode is being developed under the auspice of the Canadian Department of National Defence. MODEX, or the more generic term along-track interferometry, is

designed to detect, measure and monitor moving objects on the Earth's surface. By partitioning the SAR antenna into two sub-apertures – aligned in the direction of flight – the satellite can image successive scenes. The comparison of the scenes shows any movement or change in location during the intervening imaging time. Nominal minimum-detectable speed for moving targets such as vehicles is in the 5 m/s range.

SpotLight Mode

The configuration for conventional SAR imaging is for the radar beam to be transmitted perpendicular to the platform flight direction. In SpotLight mode, the radar beam “squints” forward and backward, that is the radar beams images in the off-perpendicular direction. Using this squinting process, the target is illuminated by the radar beam longer than conventional imaging. The longer illumination time results in improved resolution, which for RADARSAT-2 is projected to be about 1 m.

5.0 RADARSAT-2 Applications: Information and Data Requirements

RADARSAT-2 applications represent continuity from RADARSAT-1, and it is expected that the enhanced capabilities of RADARSAT-2 will provide the opportunity to develop new applications as broadly outlined below. These applications represent a synthesis of RADARSAT-2 capability in the form of access to polarimetric data, higher resolution, improved re-visit, and an enhanced ground segment.

- **Surveillance:** where maximum information is required over relatively small spatial areas (e.g., a military base or harbour). RADARSAT-2 polarimetric data, higher resolution and improved geospatial location accuracy address these requirements.
- **Classification and change detection:** involves monitoring of large areas with as much information as possible (e.g., for crop classification, crop yield estimate, and change detection). Large swath widths (> 130 km) and multi-polarization data are ideal for this application.
- **Near real-time response:** where frequent imaging, and fast processing and delivery are essential (e.g., for monitoring of oil spills and floods). The RADARSAT-2 system offers expedited responsiveness via short programming lead time, higher revisit capabilities from the left/right imaging capabilities, and fast processing turn-around time, enabling improved information to support these applications.

The provision of information to end-users in an interpretable and interoperable format is a fundamental component of the RADARSAT-2 program. Interpretable means the information is in a format that an end user can use or in a format that makes sense to the end user. For example, pollution control response teams likely require a map showing the location of oil relative to sensitive coastal areas, or agricultural companies may need a map showing crop type. Interoperable means that the information can be shared between users by using a GIS, for example. It is, however, important to point out that many end-users still want data. For example, defence agencies tend to want data since, for the most part, the sensitive nature of the information must remain confidential. In contrast, an

end-user involved in illegal fishing activities likely wants an information product showing, for example, the location of radar-detected fishing vessels.

6.0 Summary

RADARSAT-1 information needs have evolved since the launch of the satellite due to a variety of factors including economic cycles (e.g., for oil seep detection), better understanding of SAR technology (e.g., interferometric SAR), and adoption of SAR-derived information products (e.g., for maritime surveillance). While certain applications are expected to be dominant in the early RADARSAT-2 mission, it is likely that these applications will also evolve with time. For example, the use of quad-polarized data is unlikely to be used extensively early in the mission life, but as users develop an understanding on how to exploit the data, and as exploitation tools are developed, use of the data should increase dramatically.

The RADARSAT-2 program is an excellent example of public-private partnerships joining forces to, in this case, commercialize a spaceborne SAR program. The advanced features of RADARSAT-2 will keep Canada in the forefront of spaceborne SAR by providing end-users and researchers with access to high resolution, multi-polarized SAR data, supported by an efficient ground segment designed to deliver data in a timely manner. It is projected that the advanced features of RADARSAT-2 will open-up new applications for SAR-derived information, in addition to providing continuity for well-established RADARSAT-1 applications such as ice mapping and maritime surveillance. Looking to the future, it is anticipated that the value of the information derived from RADARSAT-2 data will serve as the impetus for continuity of spaceborne SAR missions.

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