

# PERFORMANCE EVALUATION OF ERS-1 SYNTHETIC APERTURE RADAR FAST DELIVERY PROCESSOR

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## Abstract

The Factory Acceptance Test (FAT) of ESA's ERS-1 Synthetic Aperture Radar Fast Delivery Processor (SAR FDP) took place recently at MacDonald Dettwiler in Vancouver, Canada. The processor will eventually be installed in the principal ERS-1 ground station in Kiruna, Sweden.

This paper describes the comprehensive set of tests performed during the FAT. It focusses on the tests and measurements of:

- image quality parameters (3-dB resolution, side lobe level, etc);
- throughput for both image and wave mode product generation;
- operational aspects of the processor demonstrating its ability to run in an operational environment.

The SAR FDP shows a significant improvement in throughput compared to previous SEASAT processors, while preserving the integrity of the image quality.

## 1.0 Introduction

The development of the ESA ERS-1 satellite offers an opportunity to develop a fast processor for Synthetic Aperture Radar (SAR) data.

The key requirement is to minimize the delay between data acquisition and delivery of processed images to users. A maximum delay of three hours is allowed for both the image and wave modes. In the image mode the satellite acquires SAR data for 100 x 100 km earth surface images. In the wave mode SAR data is acquired for 5 x 5 km images of the ocean surface at along-track intervals of 200 or 300 km. The SAR FDP processes wave mode data to an intermediate image, and then to a final image spectrum product. Sea state information (wave spectrum product) will be derived from the image spectrum product. The

image mode operates only while the satellite is visible from a ground station, while the wave mode can operate around the orbit, since data can be recorded on-board and later downlinked to the ground station (see [1]).

The features of a SAR processor capable of meeting such a requirement while preserving the quality of the product have been defined and an ESA contract placed with MacDonald Dettwiler for the processor's development. Development based on the design presented in [2] is now complete, and this paper describes the processor's actual performance.

## **2.0 Methodology**

The SAR FDP was tested against all detailed requirements stated in the SAR FDP requirements specifications. A verification cross reference matrix was used to map each requirement to the test number in the acceptance test procedures document.

A total of 16 main tests, each of them consisting of various subtests, were developed. These tests were designed to demonstrate that the SAR FDP meets its image quality requirements as well as its operational requirements.

The image quality tests were done by processing simulated point targets as well as pre-processed SEASAT data and then analysing the processed images. The operational aspects of the processor were tested by scheduling the processor to generate all possible products from image mode and wave mode data. The processor was also tested against possible errors in commands from the control computer, or in the input raw data.

## **3.0 Test Data Specifications**

### **3.1 Simulated Point Targets**

Point target data is generated using a specially developed simulator running on the ST-100 array processor (developed and manufactured by STAR Technologies Inc.). Both image mode and wave mode data are simulated using ERS-1 parameters and copied to High Density Digital Tape (HDDT), which conforms to the ERS-1 downlink format.

Parameters are chosen to simulate extreme conditions such as maximum squint angle and maximum and minimum pulse repetition frequencies.

Point target positions are chosen to allow image quality measurements across the whole image. In particular, point targets are placed at the boundaries of the processor range invariance regions to demonstrate that image quality parameters are not degraded by any implementation specific restrictions.

### 3.2 Simulated Wave Data

The simulated wave data is used to test generation of the image spectrum product, which is the final SAR FDP wave mode product.

The wave data is approximated as a sinusoidal function characterized by its wavelength and direction.

Several data sets are generated using different wavelengths and directions so the averaging process and the rectangular to polar coordinates transformation during spectrum product generation can be tested extensively.

### 3.3 Pre-processed SEASAT Data

Pre-processed SEASAT data is used to demonstrate that the SAR FDP can process real SAR data with image quality parameters comparable to those produced by MacDonald Dettwiler's SEASAT processor.

The pre-processing includes shifting the SEASAT data to baseband frequency so that the raw data is represented as complex numbers (real and imaginary parts) rather than as real numbers. Furthermore, the data is converted to 5-bit to resemble ERS-1 data and then copied to HDDT to conform with the ERS-1 downlink format.

### 4.0 Performance Test Results

The performance tests include image quality parameter measurements such as spatial resolution, side lobe level, Integrated Side Lobe Ratio (ISLR), and also throughput measurements. Typical results of the measurements are shown below. These results are compared with the values stated in the processor's requirements specification.

#### 4.1 Spatial Resolution and Side Lobe Level

The spatial resolution is the 3-dB width of the point target response measured in both range and azimuth directions. The side lobe level is the highest side lobe level in the point target response relative to the main peak level. Results from the simulated point target data are as follows:

	Requirement	Measured
3-dB width in slant range:	< 1.44 pixels	1.29 pixels
3-dB width in azimuth:	< 1.66 pixels	1.35 pixels
side lobe level in range :	< -20.0 dB	-24.5 dB
side lobe level in azimuth:	< -20.0 dB	-24.1 dB

Spatial resolution of the SEASAT image is also measured and compared with the image processed by the original SEASAT

processor. Two SEASAT scenes, Goldstone and Vancouver, are used for the test. The result is as follows:

	SEASAT Processor	SAR FDP
3-db width in ground range:	24.8 metres	25.2 metres
3-db width in azimuth:	22.0 metres	22.3 metres

Figure 1 shows the Vancouver scene processed by the SAR FDP.



FIGURE 1 SEASAT VANCOUVER SCENE PROCESSED BY THE SAR FDP

#### 4.2 Integrated Side Lobe Ratio (ISLR)

The integrated side lobe ratio is the ratio expressed in dB between the side lobe power and the main lobe power of the response from a point target. The main lobe power is the total power inside an area centered about the main peak and extending three resolution lengths in the range and azimuth directions. The side lobe power is the total power outside the main lobe but within an area bounded by ten resolution lengths in the range and azimuth directions.

The result of this ISLR measurement is -20.0 dB while the stated ISLR requirement is that the value be less than -12.0 dB.

#### 4.3 Point Target Misregistration

The point target misregistration is the misregistration of a point target's energy from its expected zero doppler location caused by approximations in the SAR processor. Misregistration due to orbit data and terrain height error is not included.

The results of the misregistration measurements are as follows:

	Requirement	Measured
Range misregistration	± 2.88 pixels	0.47 pixel
Azimuth misregistration	± 3.32 pixels	1.56 pixels

#### 4.4 Radiometric Linearity

Radiometric linearity is measured by the correlation coefficient between output point target peak power regression and input point target power.

The simulated point target data is generated with varying power so that the data cover the dynamic range of the ERS-1 input data. The radiometric linearity value is required to be greater than 0.95, and the measured value is 0.98.

#### 4.5 Product Localisation

The SAR FDP is required to compute the geographical position of the four corner points and the centre point of a 100 x 100 km image. The geographical positions are expressed in terms of geodetic latitude and longitude.

The computation is checked by comparing results with those obtained from an independent software program developed by ESA. Typical results are as follows:

	Latitude	Longitude
ESA program result	36.369°	239.338°
SAR FDP result	36.369°	239.337°

## 4.6 Throughput

The SAR FDP is required to generate the following image mode products within one orbit:

- three fast delivery image mode products (100 x 100 km scene);
- two image mode noise statistic and drift calibration pulse products;
- three image mode chirp replica products.

If the SAR FDP is configured to process wave mode data it is required to generate the following products within one orbit:

- 150 wave mode intermediate products (5 x 5 km scene);
- 150 fast delivery wave mode products (image spectrum);
- ten wave mode noise statistic and drift calibration pulse products;
- 150 wave mode chirp replica products.

The throughput has to be sustained from orbit to orbit for up to ten consecutive orbits. Considering all ground station operational restrictions such as data acquisition and HDDT positioning, the SAR FDP is required to generate one fast delivery image mode product in less than 28 minutes. The tests show that one 100 x 100 km image mode scene can be generated in 27.3 minutes.

Similar consideration of the ground station operational restrictions during low rate data processing shows that one chirp replica, one intermediate and one image spectrum wave mode product must be generated in less than 28 seconds. The throughput measurement during the test shows these products can be generated in 26 seconds.

## 5.0 Operational Aspects

The operational aspects of the SAR FDP are tested by scheduling the processor to generate all possible combinations of products. These include all the products listed for the throughput tests plus extraction products such as raw data products, general header products, and instrument header products. All products are checked against the output product specifications in terms of their formats and expected values in the product headers.

In addition, several tests are designed to test the error handling strategy of the SAR FDP. The simulated errors include

the following:

- errors in the command parameters (inconsistent parameters)
- invalid commands
- errors in the system software configuration (e.g. a missing parameter table)
- missing lines in the input data
- insufficient input data
- overlapping and obsolete wave mode source packets
- error in spacecraft time code
- range line counter wrap around (caused by the 16-bit representation)

The SAR FDP is verified to handle these possible errors correctly. The verification was done by examining the SAR FDP responses and also the generated products.

## 6.0 Conclusion

The SAR FDP as developed by MacDonald Dettwiler under the ESA contract represents the newest implementation of the well proven SAR range-doppler algorithm.

The development's most significant achievements are its processing speed improvement (27 minutes per image compared to a few hours) and its preservation of image quality in a ground station operational environment.

## 7.0 Acknowledgement

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## 8.0 References

- [1] G. Duchossois "Overview and status of the ERS-1 programme." *Proceedings of IGARSS '86 (ESA SP-254 Vol. 1)*, August 1986.
- [2] P. George & J.P. Guignard "ERS-1 Synthetic Aperture Radar Fast Delivery Processor." *IEEE Transactions on Geoscience and Remote Sensing*, Vol. GE-25, No.6, November 1987.