INSTRUCTIONS TO AUTHORS FOR THE PREPARATION OF PAPERS FOR THE OCEANOBS '09 CONFERENCE PROCEEDINGS DIRECTIONAL WAVE SPECTRUM ESTIMATION BY SWIM INSTRUMENT ON CFOSAT

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Oceanography greatly benefits from remote sensing satellites for global monitoring and forecast of the sea state. The CFOSAT (China France Oceanography SATellite) mission, whose launch is planned for 2013, should embark two radar payloads to monitor wind and waves over the ocean. One of these two radar instruments is called SWIM (Surface Waves Investigation and Monitoring). It is a scatterometer designed to measure ocean waves based on the Jackson et al.'s concept [1,2].
The ocean wave spectra provide information on the distribution of wave energy (or wave height) with respect to wavelength and wave propagation direction. These features are of main interests for ocean wave monitoring and forecast. The selected sun synchronous orbit (characterized by an altitude of 514 km and a 13-day cycle) ensures a nearly full coverage of the oceans.

1. DESCRIPTION OF THE SWIM INSTRUMENT

SWIM [3,4] aims at measuring directional ocean wave spectra at a scale of about 70 x 70 km² on a 180 km wide swath with a minimum detectable wavelength of about 70m and an angular resolution better than 15°. It is dedicated to three measurements:

- backscattering coefficient from 0° to 10° incidence,
- significant wave height and wind speed (estimated from the nadir beam),
- wave directional spectra (from 6°to 10° incidence).

1.1. Architecture

SWIM is a real aperture radar in Ku-band pointing sequentially at six different incidences (from 0° to 10°) with a constant azimuth scanning (Fig. 1). The acquisition durations spent on each incidence angle are called cycles. The global incidence coverage [0°-10°] lasts a "macro cycle" of 218 ms.

The transmitted signal is a chirp, a linearly frequency modulated pulse, with a 320 MHz bandwidth and a 50 µs time length. On each beam, backscattered signals are received and digitally compressed in range onboard, allowing to reach a range resolution of about 47cm.
Besides, each beam's PRF (Pulse Repetition Frequency) is selected in order to maximize the number of independent echoes, under some constraints such as the duty cycle of the high power amplification subsystem and the Tx/Rx chronogram.

SWIM is made of four main units:
- a radio-frequency unit gathering all the analog functions of a radar (bandwidth expansion, frequency translations, local oscillator generation, low noise amplification, base band conversion, bandwidth filtering), amplifying the signal through the TWTA and directing the signal through emission, reception or calibration paths in the duplexer;
- a digital processing unit gathering all the digital (hardware and software) processing of the whole instrument (digital chirp generator, digital compression, range migration correction, radar echoes processing, instrument interface with the platform computer);
- an antenna unit constituted of a structure, a fixed offset reflector antenna, a Rotary Mechanism Assembly integrating the motor, bearings, a RF rotary joint and a DC rotary joint, a Rotary Feed Assembly integrating the plate with the 6 horns and a 5-switch matrix allowing to transfer the RF signal from the unique entry port out of RF rotary joint to one of the 6 desired output ports, each at the bottom of the dedicated horn;
- a SWIM interface unit dialoging on the one hand with the platform (power and TM/TC), and on the other hand with the different SWIM units.

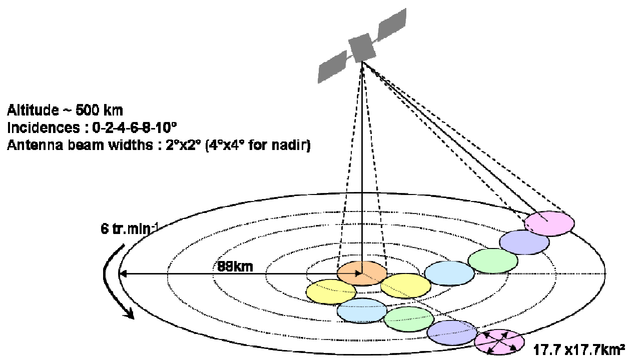

Figure 1. SWIM instrument

1.2. On-board processing

The pulses acquired during each cycle are averaged in time and in range in order to reduce speckle and thermal noise. For data downlink constraints, the averaging (at least in time and partly in range) has to be performed

on-board.
Due to satellite advection and antenna rotation, the beam footprint is moving during acquisition time (migrations) [1]. For a given fixed target in the surface spot, migrations induce range variations from one pulse to the other. It implies that a registration has to be performed on-board, so that a good overlap of the target contribution in the echoes through the averaging process is guaranteed between the beginning and the end of each cycle. The proposed registration algorithm [4] is based on "chirp scaling" which has been defined for the focusing of SAR images.

The processing has to be performed at a high rate (until 7 kHz) on 32768 complex samples.

2. SWIM PERFORMANCES

At a first level, the instrument performances are quantified through the analysis of the SNR budget and the radiometric resolution at cycle time scale. The SNR is varying from 14 dB, at nadir, to 4.5 dB, at 10°, in the centre of the beam. This guarantees an accurate estimation of the radar cross-section estimation, as long as the calibration of the emission and reception chains is precise enough. The scientific requirement is about +/-0.5 dB of absolute accuracy and +/-0.1 dB of relative accuracy between beams. To reach such accuracy, four internal calibration modes are implemented on-board to calibrate almost all the instrument parts.

Nevertheless, the link between instrument first level performances and wave spectrum retrieval is not straightforward. A simulation tool, called SimuSWIM, has been developed to derive the quality estimation of waves from the SWIM characteristics. SimuSWIM is an end-to-end simulator whose main steps are:
- simulation of the sea surface knowing analytical wave spectrum,
- computation of measured backscattered intensity,
- signal inversion to estimate wave spectrum,
- comparison of the estimation with the input spectrum.

Fig.2 proposes an example of a theoretical spectrum used as input and the corresponding estimated one, taking into account the up-to-date SWIM definition.
As automatic comparisons are not easy, some analysis tools are under development to automatically partition the spectrum into main sea states and calculate the associated geophysical parameters such as propagation direction, dominant wavelength, energy, etc.

Until now, theoretical analyses and simulations have confirmed that SWIM design is compliant with scientific requirements.

3. CONCLUSION

SWIM is a new concept of real aperture radar that requires going through new developments of architecture. It shall provide not only with great breakthroughs in the wave observation field but also in technologies in support of the development of future radars.

4. REFERENCES

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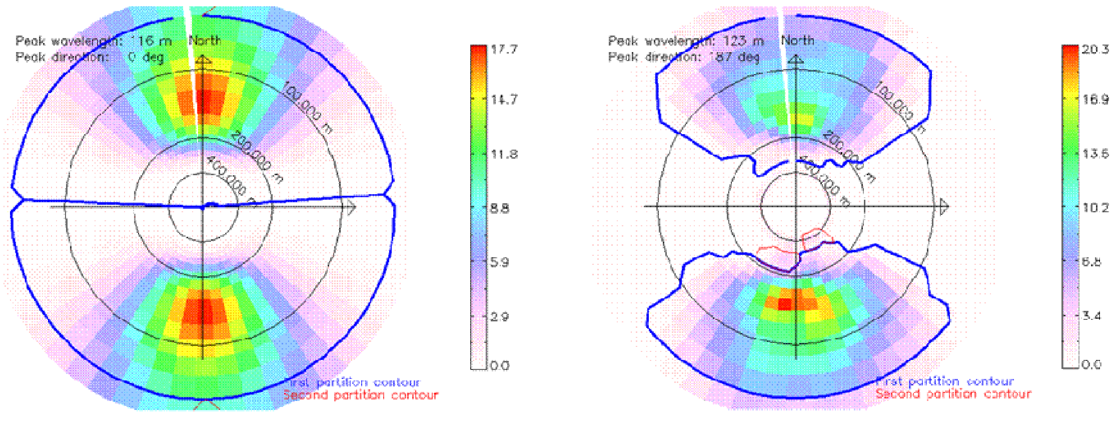

(a) Reference 2D wave spectrum (b) Estimated 2D wave spectrum

Figure 2. Simulated 2D wave spectra for Pierson-Moskowitz model (U=13 m.s^{-1}) after inversion (right) compared to the analytical reference (left). The blue curves are the result of the automatic partitioning. The resulting peak wavelength and peak direction are noted on the figure (left top). The 180° ambiguity in direction is not removed in the example.