# SeaWinds on QuikSCAT: Sensor Description and Mission Overview

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*Abstract*— The *SeaWinds* instrument is the first "pencil-beam" scatterometer to routinely measure ocean surface winds from space. Developed to fly on-board the Japanese ADEOS-II mission, the first flight of *SeaWinds* was moved up several years when the ADEOS-I satellite carrying the NASA Scatterometer (NSCAT) failed. Utilizing only a one year development time, a dedicated small spacecraft was purchased and the *SeaWinds* flight hardware was adapted for flight. The *SeaWinds* on *QuikSCAT* mission was successfully launched on June 19, 1999. Here, the *QuikSCAT* mission, the *SeaWinds* instrument, and the *SeaWinds* ground data processing are briefly described.

## INTRODUCTION

In June 1997 the NASA Scatterometer (NSCAT) ceased to operate due to a power failure aboard the ADEOS-I host spacecraft. This created a extensive gap in the Ku-Band scatterometer wind data base because *SeaWinds*, the follow-on to the NSCAT instrument, was not scheduled to fly on ADEOS-II for several years. In order to resume the flow of scientifically important ocean surface wind data as quickly as possible, an innovative approach was selected. The *SeaWinds* flight spare hardware would be integrated to a small satellite bus and launched within a year's time. This mission would fill the gap in data until such time as the originally planned *SeaWinds* instrument could be launched on ADEOS-II. NASA's Rapid Spacecraft Acquisition program was used to purchase a small satellite bus from Ball Aerospace, and the new mission was dubbed "*QuikSCAT*." On June 19, 1999, two years after NSCAT failed and a full two and a half years before ADEOS-II was expected to fly, *QuikSCAT* was successfully launched into orbit aboard a Titan-II booster from Vandenberg Air Force Base.

## *QUIKSCAT* MISSION

The *QuikSCAT* spacecraft was placed in an 803 km altitude, sun-synchronous orbit. The mission has a nominal life of two years, although three years worth of consumables are available. The spacecraft is 3-axis stabilized, and has verified pointing stability better than 0.05 degress each axis. Data is downlinked to the surface at frequent intervals over ground stations in North America, Europe, and Antarctica. The raw backscatter data is processed to winds at the Jet Propulsion Laboratory which distributes the data to scientific users via the Physical Oceanography Distributed Active Archive Center (PODAAC), and at the National Oceanographic and Atmospheric Administration (NOAA) which distributes the data in near real-time (i.e., with three hours) to operational users. Daily "quick look" wind images and animations are available to the general public via the projects web site at http://winds.jpl.nasa.gov.

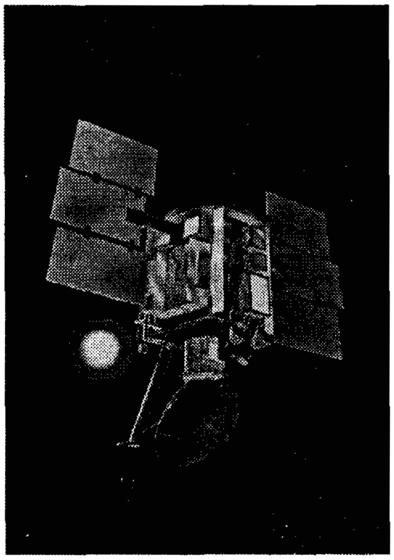

**Figure 1:** *SeaWinds on QuikSCAT.*

## *SEAWINDS* INSTRUMENT DESCRIPTION

To continue and expand upon the foundation provided by the the Seasat-A Scatterometer (SASS) and the NASA Scatterometer (NSCAT), NASA has developed the *SeaWinds* instrument. As with all scatterometers, *SeaWinds* obtains an estimate of the wind vector by measuring ocean surface radar backscatter cross section ($\sigma^o$) at multiple azimuth angles. The geophysical model function, which relates wind speed and direction to backscatter cross section, is then numerically inverted to infer the near surface wind. In a significant design departure from previously flown "fan-beam" scatterometer systems, however, *SeaWinds* is a "pencil-beam" design.

With fan-beam scatterometers, such as SASS, NSCAT, and the AMI scatterometer on the European Earth Re-

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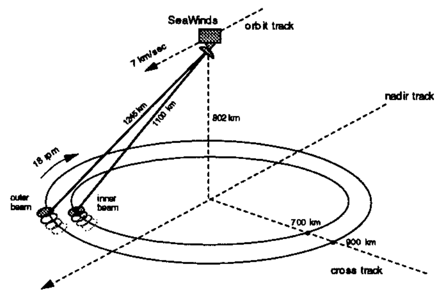


**Figure 2**: *SeaWinds measurement geometry.*

mote Sensing satellite series (ERS-1 and 2), several fixed antennas are deployed to cast long, narrow illumination patterns at the multiple azimuth angles required for wind retrieval [1]. The narrow dimension of the antenna beam pattern provides resolution in the along-track direction, and Doppler or range filtering is employed to provide cross-track resolution. The antenna structures are typically about three meters in length and require large unobstructed fields-of-view on the spacecraft.

By contrast, pencil-beam systems employ a single, approximately one meter parabolic dish which is conically scanned about the nadir axis to provide multiple azimuth measurements [2, 3] (see Fig 2). A key advantage of pencil-beam systems is that, because of their more compact design, they are much easier to accommodate on spacecraft without the necessity of complex deployment schemes or severe field-of-view constraints. In an era where smaller space missions with faster development times are often mandated – as is the case with the *QuikSCAT* mission, for example – such a reduction in payload size is highly desirable. An additional advantage to pencil-beam systems is that because they measure ocean backscatter at a constant incidence angle suitable for wind retrieval, there is no "nadir gap" in swath coverage as there is for previous fan-beam systems. The resulting contiguous swath offers a significant improvement in Earth coverage.

With *SeaWinds*, an approximately one meter diameter parabolic dish antenna with two offset feeds is used to create both the "inner" and the "outer" beams. The inner beam maintains an "off-nadir" angle of 40 degrees, and intercepts the ocean at a constant 46 degrees incidence angle. The outer beam has an off-nadir angle of 46 degrees with an incidence angle of 54 degrees. The antenna is mechanically spun about the nadir axis to generate a conical scan. As the spacecraft moves in its orbit, the beams trace overlapping helical patterns on the Earth's surface. Each point within the inner 700 km of the swath is viewed from four different azimuth angles — twice by the outer beam looking forward then aft, and twice by the inner beam in the same fashion. In the outside edge of the swath, between cross track distances of 700 and 900 km, each point on the ocean is viewed twice by the outer beam only. The inner beam is horizontally polarized with respect to the ocean surface (the transmitted E-vector is parallel to the surface). The outer beam is vertically polarized.

Note that, unlike fan-beam systems, the azimuth angle "mix" of the $\sigma^0$ measurements going into the wind retrieval is not constant, but varies from nadir out to the edge of the swath. Near nadir the forward and aft measurements are approximately 180 degrees apart, while at the extreme edge of the swath the azimuth angle between the measurements approaches 0 degrees. Thus the wind retrieval performance of SeaWinds is observed to vary as a function of the distance from the nadir track, in general being optimum when the azimuth differences of the measurements are near 90 degrees [3]. The $\sigma^0$ measurements are obtained at a favorable high incidence angle over a continuous 1800 km swath. Such a wide swath will cover 90% of the ocean surface within 24 hours, an improvement over the NSCAT coverage of 77% in 24 hours (see Fig. 3.).

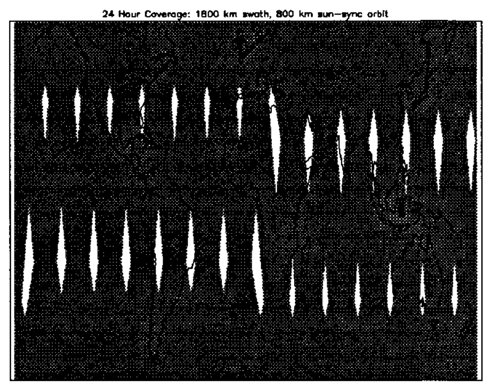


**Figure 3**: *SeaWinds 24-hour Earth coverage.*

The SeaWinds antenna rotation rate and measurement timing were chosen to obtain optimal sampling of the surface $\sigma^0$ and to meet host spacecraft dynamics requirements. The antenna rotation rate of 18 rpm combined with the nominal transmitter pulse repetition frequency (PRF) of 92.5 Hz for each beam, produces a regular pattern of measurements on the surface. The "along scan" spacing of the measurements is a function of the scan rate and PRF, and is 15 km for the inner beam and 19 km for the outer beam. The "along track" displacement of the measurements is determined by the satellite ground speed of 6.6 km/sec, and is 22 km for both beams.

Figure 4 depicts the basic design of the SeaWinds radar electronics and shows the transmit, receive, and detector

| Parameter | Inner Beam | Outer Beam |
|---|---|---|
| Polarization | H | V |
| Elevation Angle | 40° | 46° |
| Surface Incidence Angle | 47° | 55° |
| Slant Range | 1100 km. | 1245 km. |
| 3 dB Beam Widths | 1.8° × 1.6° | 1.7° × 1.4° |
| 2-way 3 dB Footprint | 24 × 31 km | 26 × 36 km |
| Peak Gain | 38.5 dBi | 39 dBi |
| Rotation Rate | 18 rpm | |
| Along Track Spacing | 22 km. | 22 km. |
| Along Scan Spacing | 15 km. | 19 km. |

Table 1: *SeaWinds* Antenna Parameters

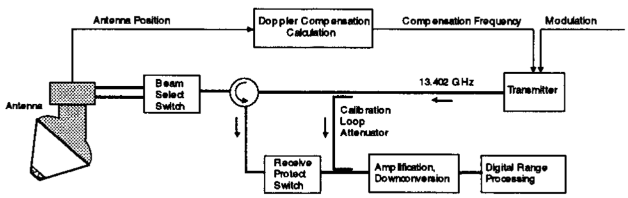


**Figure 4**: *SeaWinds system functional diagram.*

functions. Upon command from the timing controller, the transmitter, which consists of a modulated signal generator driving a traveling wavetube (TWT) amplifier, issues a 1.5 ms duration, 110 Watt Ku-Band pulse. The pulse is modulated with a FM linear chirp, and de-ramp processing is employed to allow resolution of the antenna footprint into a series of range "slices" (see Figure 5). These slices allow better registration of the backscatter data previous to wind processing, as well as enable higher resolution land and ice images to be constructed [2].

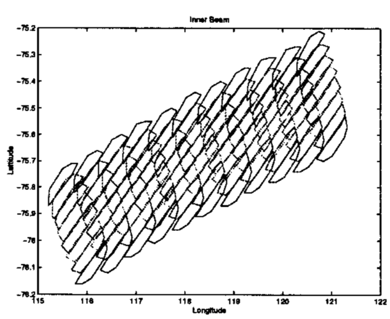


**Figure 5**: *SeaWinds range "slices".*

Due to the motion of the satellite relative to the Earth, a Doppler shift of between ±500 kHz is imparted to the echo return signal, depending on the antenna scan position. In the SeaWinds design, the Doppler shift is precompensated by tuning the transmit carrier frequency to 13.402 GHz $-f_{dop}$, where $f_{dop}$ is the expected frequency shift to be imparted to the return signal. The compensation frequency is computed by the SeaWinds on-board processor using the measured antenna position, orbit location, spacecraft velocity, and Earth rotation.

An important feature of any scatterometer system is the accurate calibration of the transmit power and receiver gain. In the SeaWinds instrument design, these parameters are measured simultaneously by periodically injecting the transmit pulse, attenuated by a known amount, into the receiver. To avoid corruption by spurious leakage power during a "loop-back" calibration event, a high loss receive protect switch is enabled.

## THE FUTURE

As of this writing, the *SeaWinds* instrument aboard the *QuikSCAT* spacecraft continues to perform perfectly. In November of 2001, the second *SeaWinds* instrument aboard the ADEOS-II spacecraft is scheduled to launch. These mission insure that a continuos data set of Ku-Band wind scatterometer is available for important climate studies.

## REFERENCES

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