THE SURFACE CONTOUR RADAR, A UNIQUE RADAR REMOTE SENSING INSTRUMENT

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ABSTRACT

An 8 mm computer controlled airborne radar has been developed by NRL and NASA WFC which generates a false-color coded elevation map of the sea surface below the aircraft in real-time and can routinely produce ocean directional wave spectra with off-line data processing.

The Naval Research Laboratory and the NASA Wallops Flight Center have jointly developed a unique radio-oceanographic remote sensing instrument under the NASA Advanced Applications Flight Experiment (AAFE) Program. The 8 millimeter airborne Surface Contour Radar (SCR) remotely produces a real-time topographical map of the sea surface beneath the aircraft. Figure 1 shows the general measurement geometry.

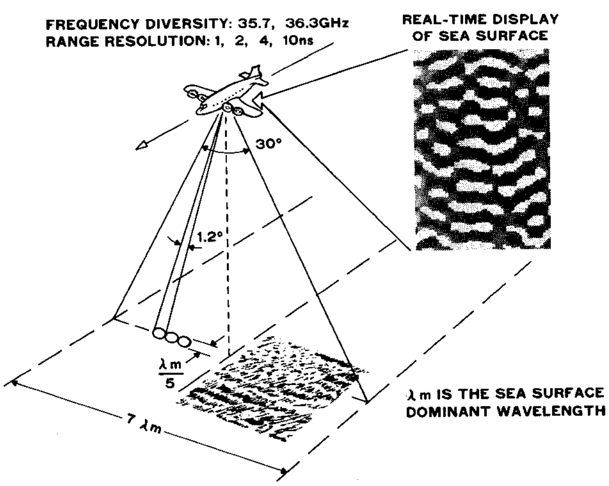

Figure 1. AAFE Surface Contour Radar (SCR) measurement geometry.

Figure 2 is a block diagram of the transceiver section of the radar. The transmitter is a coherent dual-frequency device that uses pulse compression to compensate for the limited available power at Ka band. The radar has selectable pulse widths of 1, 2, 4, and 10 nanoseconds. The transmitting antenna is a 58 λ horn fed dielectric lens whose axis is parallel to the longitudinal axis of the aircraft. It illuminates an elliptical mirror which is oriented 45° to the lens' longitudinal axis to deflect the beam towards the region beneath the aircraft. The mirror is oscillated in a sinusoidal fashion through mechanical linkages driven to a variable speed motor to scan the transmitter beam (1.2° x 1.2°) within ± 16° of the perpendicular to the aircraft wings in the plane perpendicular to the aircraft flight direction. The receiving antenna is a fan beam lens corrected compound sectoral horn with a 1.2° x 40° beamwidth so the 3 dB two-way beamwidth is 0.85° x 1.2° for a resolution of h/70 along-track by h/50 cross-track where h is the aircraft altitude.

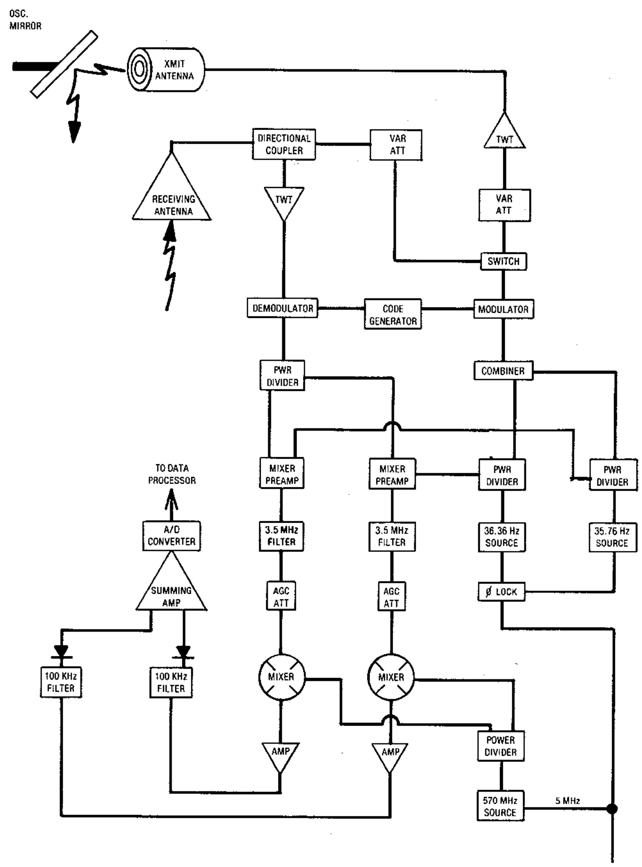

Figure 2. Block diagram of SCR transceiver section.

The radar was designed to remotely produce real-time topographical maps of the ocean surface. It makes 51 individual range measurements in each cross track antenna scan within a swath width equal to h/2. The application of a two dimensional Fast Fourier Transform (FFT) to the ocean elevation arrays produces a direct measurement of the ocean directional wave spectra.

The design of the system necessitated several trade-offs in system parameters to achieve both high spatial and high range resolution. The transmitted frequency was arrived at by compromising between the inherent high spatial resolution with moderate apertures at 90 GHz and the ease of generating 1 nanosecond pulses below 18 GHz. An electronically scanned phased array was considered for the transmit antenna but was eliminated for three reasons: (1) lack of

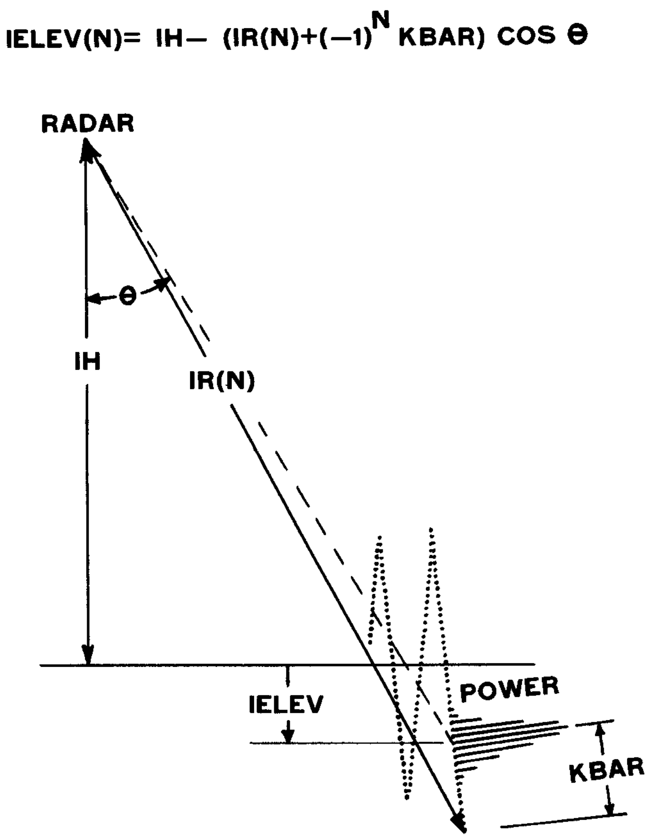

Figure 3. Method of real-time computation of surface elevations from data.

necessary bandwidth, (2) tendency to vary pointing with frequency, and (3) cost. At 36 GHz a moderate size elliptical mirror (48 cm x 69 cm) could be mechanically scanned sinusoidally at 10 Hz without incurring permanent mechanical problems in the aircraft structure. The limited power available at Ka band over a 1 GHz bandwidth was a problem that was circumvented by pulse compression techniques. The CW transmitter is bi-phase modulated by a digitally generated maximal length code sequence. The return signal is autocorrelated by a like sequence with a variable time delay inserted.

A minicomputer is used as an onboard processor. Range tracking is done in software and surface elevations are calculated in real time. Figure 3 shows how the elevations are computed. The computer interacts with the radar hardware only once for each lateral scan of the transmitter beam. As the beam is scanned laterally, the range is scanned in a predetermined saw-tooth pattern which depends on the roll attitude of the aircraft and is designed to keep the region interrogated symmetric with respect to mean sea level. On each of the 51 range scan legs the radar hardware sums and stores the returned power and the range-weighted returned power (referenced to the start of the scan). The 102 values are drawn into the computer at the end of the angular scan. The sum of the range-weighted power is divided by the sum of the power to determine KBAR, the centroid of the return power. The equation to determine the elevation is shown at the top of Figure 3 where the index N specifies one of the 51 range scan legs. Range increments on even numbered legs and decrements on odd legs. Surface contours are false-color coded and displayed in real-time on a 48 cm color display.

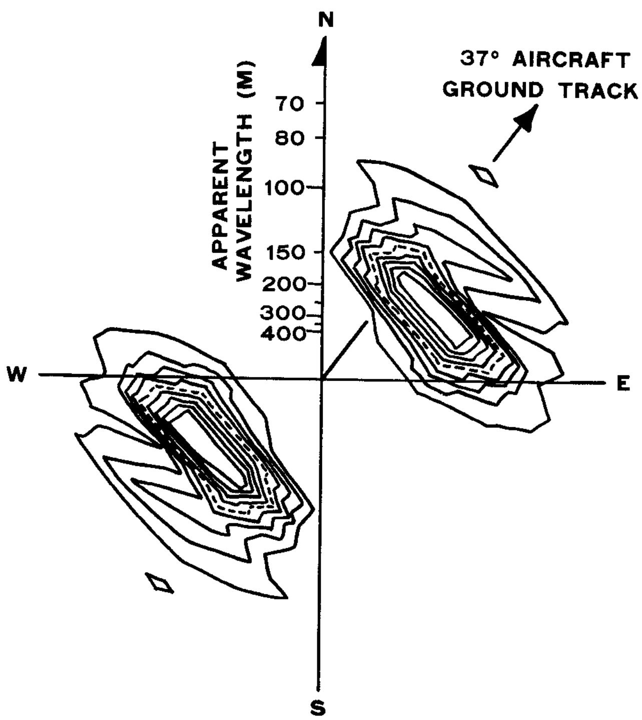

Figure 4. Normalized directional wave spectrum (10% contour interval, 50% contour dashed) for wind driven waves of 5.5 m SWH. Data swath width was 220 m and aircraft heading into the wind.

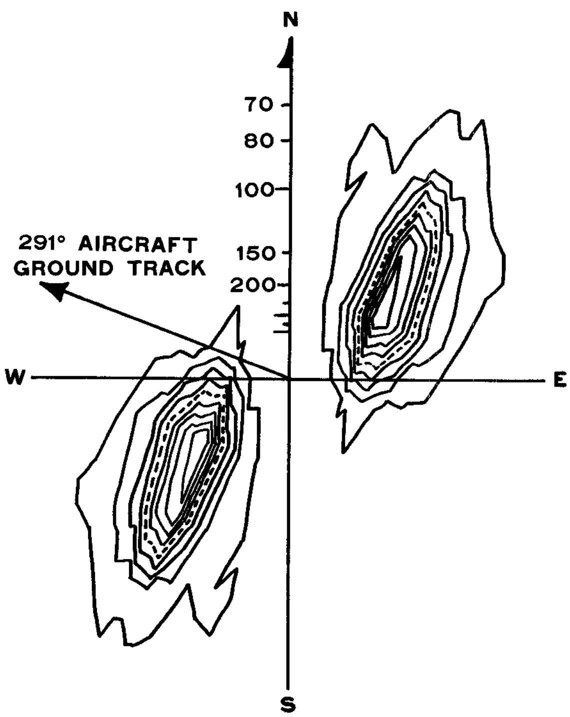

Figure 5. Normalized directional wave spectrum for same wave conditions as Figure 4 but with aircraft heading perpendicular to the wind.

Off-line data processing applies doubly integrated accelerometer information that is taken simultaneously with the elevation data to remove aircraft motion from the data. The surface elevation distribution and the relative radar backscatter distribution can be calculated along with the standard deviation, skewness, and kurtosis of both distributions. Figures 4 and 5 show the first ocean directional wave spectra computed by a two-dimensional FFT of the elevation arrays for upwind and crosswind aircraft flight directions for the same surface conditions. The contour interval is 10% of the peak value and the 50% contour is dashed. The distortion results from having too narrow a swath to properly determine the cross-track characteristics of the spectrum. The surface wind was 35 knots with gusts to 45 knots and the data was taken with clouds and driving rain obscuring the surface. The system was power limited at the time the data was taken (but no longer) so the data was collected with the aircraft at an altitude of 440 m. The resulting swath width of 220 m was only 1.6 dominant wavelengths wide instead of the nominal ideal of 7. The resulting blossoming of the spectra in the cross-track direction due to the narrow swath is apparent. But even in this case a correct spectrum could be generated by combining the along-track information from the two flight directions.

The ability to easily and directly measure directional wave spectra will be extremely useful in developing oceanographic models as well as validating indirect remote sensing oceanographic techniques such as side-looking radars.