NASA TM-84440

SQT

REMOTE SENSING OF DIRECTIONAL WAVE SPECTRA USING THE SURFACE CONTOUR RADAR

E. J. Walsh, D. W. Hancock, III, D. E. Hines
NASA Wallops Flight Center
Wallops Island, VA 23337

J. E. Kenney
Naval Research Laboratory
Washington, DC 20375

ABSTRACT

The Naval Research Laboratory and the NASA Wallops Flight Center have jointly developed a unique radio-oceanographic remote sensing instrument (Kenney, et al., 1979). The 36 GHz airborne Surface Contour Radar (SCR) remotely produces a real-time topographical map of the sea surface beneath the aircraft. It can routinely produce ocean directional wave spectra with off-line data processing. 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 °.

(NASA-TM-84440) REMOTE SENSING OF DIRECTIONAL WAVE SPECTRA USING THE SURFACE CONTOUR RADAR (NASA) 4 p HC A02/MF A01 CSCL 08B
N85-24510
Unclas
G3/43 21066

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 its swath. 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 SCR 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 phase array was considered for the transmit antenna but was eliminated for three reasons: (1) lack of 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 mechanically 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. 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 stores the peak returned power value and its range (referenced to the starting range of the leg).

The 102 values are drawn into the computer at the end of the angular scan. The angle off-nadir is measured and used with the slant range to determine the elevation of the surface with respect to the horizontal reference level. The surface elevations are false-color coded and displayed in real-time on a 48 cm color display. The quantities recorded on magnetic tape at the end of each antenna scan include: the raw radar data, the computed elevations, and miscellaneous parameters used for housekeeping and to maintain antenna scan and range scan synchronization, the aircraft LTN-51 Inertial Navigation System (INS) information (latitude, longitude, ground speed, ground track, heading, roll), date, and time of day. Nearly all of the real-time computation performed by the computer used integer arithmetic to minimize running time. Quantities of length and time are normalized by Δr, the radar range resolution, and Δt, and 11 μ s range scan rate period, respectively, and dealt with as integers. Scaled integer arithmetic is used wherever necessary to maintian accuracy.

The typical aircraft velocity is 100 m/s and the SCR can produce raster lines of elevation by scanning a pencil beam perpendicular to the aircraft flight direction at the rate of 20/s. If the aircraft altitude is h then each scan line produces 51 elevation data points of resolution h/70 along track by h/50 cross-track with lateral separation of h/100 within a swath of width h/2. The along track separation of the raster lines would be 5 m. Typically 1024 scan lines over an along-track distance of 5 km that are used in the FFTs which provides high along-track resolution. There is a compromise to be made between high altitude to provide wide swath for high resolution of propagation direction and low altitude to provide high spatial resolution. The SCR typically acquires data at altitudes of 200 m to 800 m.

Directional wave spectra are computed by applying a two-dimensional FFT of the elevation arrays. When the SCR spectra are compared with data from pitch-and-roll buoys they are seen to have the same dominant wave direction and frequency content. The main disparity is that the SCR spectra have half-power widths in the 30° to 45° range whereas the pitch-and-roll buoys have widths in the 90° and 130° range. 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 and wave spectrometers.

Reference

Kenney, J. E., E. A. Uliana, and E. J. Walsh, "The Surface Contour Radar, A Unique Remote Sensing Instrument," IEEE Trans. Microwave Theory Techniques, MTT-27, No. 12, Dec. 1979, 1080-1092.