NANOSECOND RADAR OBSERVATIONS OF THE OCEAN SURFACE FROM A STABLE PLATFORM

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INTRODUCTION

Radar as a remote sensor of ocean surface conditions has been in use for sometime. These radars, using either CW or long pulse modulation require that the measurements be taken at various look angles. The ocean surface conditions are inferred from the steepness of the curves of reflected energy versus angle. However, if one were to reduce the pulse width of the radars until the pulse width resolves the vertical water wave structure and looks only in the direction normal to the ocean surface, an entirely different set of radar returns are available to describe the ocean surface characteristics. This paper will describe some preliminary results obtained by measuring the ocean surface with a nanosecond radar pulse from a fixed platform at vertical incidence.

RADAR SYSTEM DESCRIPTION

A simplified block diagram of the radar system is shown in Figure 1. The transmitted one nanosecond pulse is generated by rapid pulsing of a step recovery diode which is mounted in an x-band waveguide (WR-90). The diode output is amplified by a TWT amplifier and fed to a transmitting antenna. Duplexing is achieved using separate transmitting and receiving antennas which provide adequate isolation. The received pulses are amplified at rf until sufficient signal is available to drive diode detectors with extremely fast response time. The detected signal is displayed on a sampling scope. The sampling scope stores the information in a manner permitting A-D conversion for recording on magnetic tape. All the synchronization of the rf signals and control signals are programmed by the control unit. The radar system parameters are:

$$\begin{aligned} P_t &= 0.1 \text{ W} \\ \text{PRF} &= 70 \text{ KHz} \\ \tau &= 1 \text{ ns} \\ \text{Antenna Diameter } D &= 76 \text{ cm} \\ \text{Antenna Beamwidth} &= 2^\circ \\ \text{Receiver Bandwidth} &= 10^9 \text{ MHz} \\ \text{Antenna Gain} &= 35 \text{ db} \end{aligned}$$

OBSERVATIONAL PLATFORM

The radar system was installed on the Chesapeake Light Tower (Figure 2) which is located about 15 miles east of Virginia Beach, Virginia. The antennas were mounted underneath the catwalk as shown in Figure 3. The antennas are about 70 feet above mean sea level and the radar illuminates a spot on the ocean about one meter in diameter. In order to calibrate the radar system, both in range and amplitude, a corner reflector held on a rigid pole was placed in the center of the antenna beam and mounted about 60 feet from the transmitting antenna (Figure 4). To provide the primary ground truth concerning the waves, three wave poles were placed in a delta configuration surrounding the radar illuminated spot. The electrical output of the three wave poles, using 0.1 second time constant, were recorded simultaneously with the radar data on magnetic tape.

DATA

Figures 5 and 6 are computer plots of the radar data as recorded. These two runs will be used to illustrate two extreme sea conditions that were recorded. Figure 5 represents a calm sea condition with moderate swells. Figure 6 corresponds to a 20 knot wind with wind driven 5-foot waves. Since the wave pole measurements are recorded simultaneously, their output is arbitrarily placed to the left or right of the radar data and their alignment in time is automatic. The plots, as shown, are an attempt to illustrate, as much as possible with one photograph, a sequence of the time history of the waves passing the radar illuminated spot. Each division of the vertical scale corresponds to one second in time. The horizontal scale measures the time delay of the radar pulse in nanoseconds, where each division corresponds to 5 ns (75 cm).

Figures 7 and 8 are plots of the power spectrum for the data of Figures 5 and 6 respectively. In addition, the wave pole power spectrum is superimposed on the radar spectrum. The agreement is so close that one can truly interchange the two results without serious error.

As mentioned earlier, a corner reflector was placed in the beam so that calibrations may be possible in power and range. The radar returns from the sea of Figures 5 and 6 were calibrated with respect to the radar return of the corner reflector. The power return was averaged for each increment of range resolution so that a plot of reflected power versus depth into the wave height is possible. Figures 9 and 10 show the reflected power versus wave depth for the two examples. The crest is to the left and the trough is to the right. Note that the reflectivity in these two cases is not uniform but increases toward the trough.

If one were to plot the effective amplitude distribution of the returned signals over the vertical water wave structure and normalize the area under the curve, one then obtains the equivalent impulse response for the sea. The returns were plotted in this manner in Figures 11 and 12 with an accompanying photograph of the sea at the time the data were taken. Superimposed is the wave pole amplitude distribution. It is seen that the effective difference between the radar and wave pole distribution is minor, and that the error introduced by the electromagnetic distortion on the derived mean height and wave heights should be small.

SUMMARY

Nanosecond pulse radar systems show promise for measuring the sea and provide information comparable with wave pole measurements. Until further analysis with additional data and thorough comparison with wave pole data, this report is intended as a preliminary discussion of progress to date.

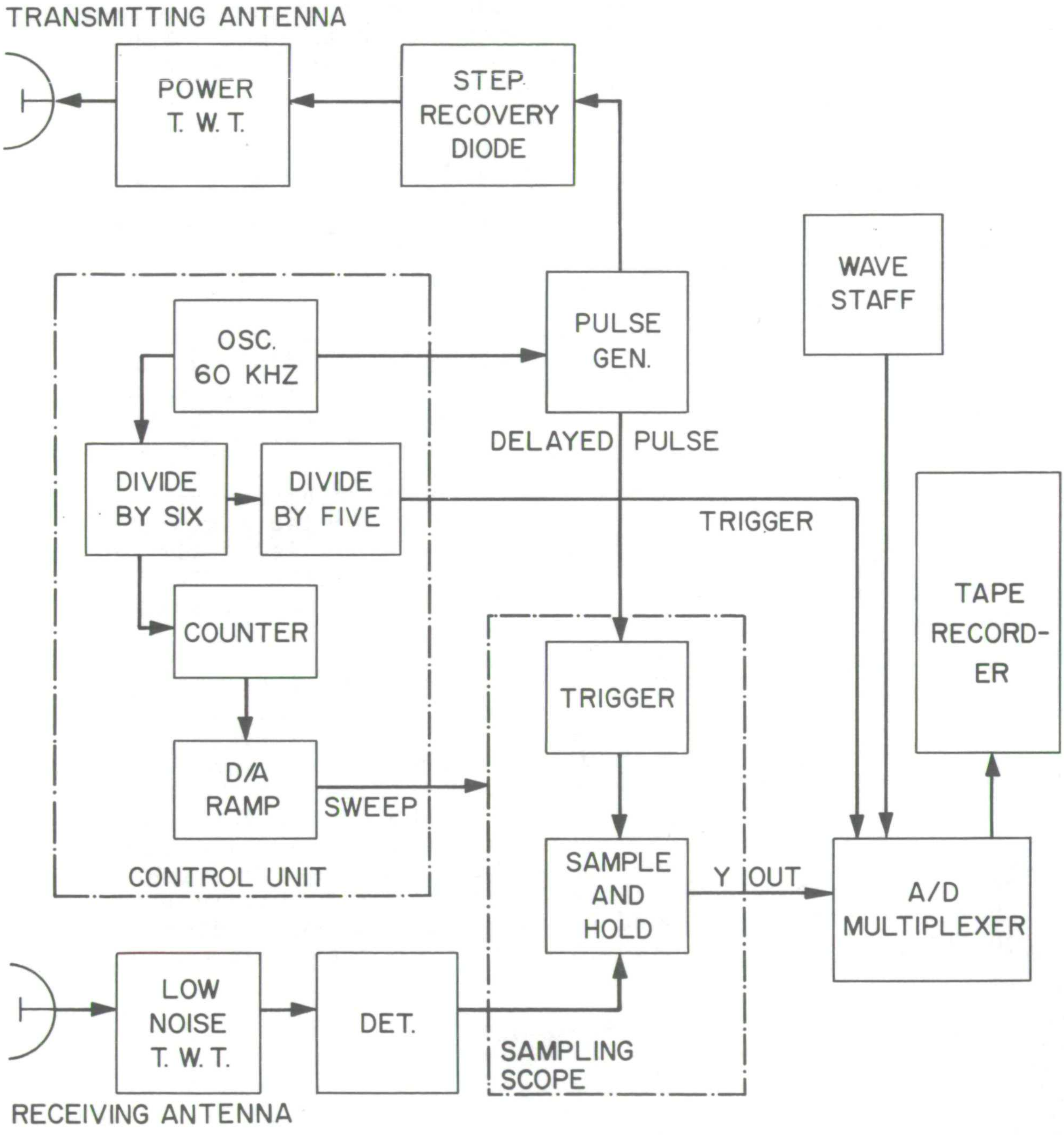


Fig. 1 Radar System

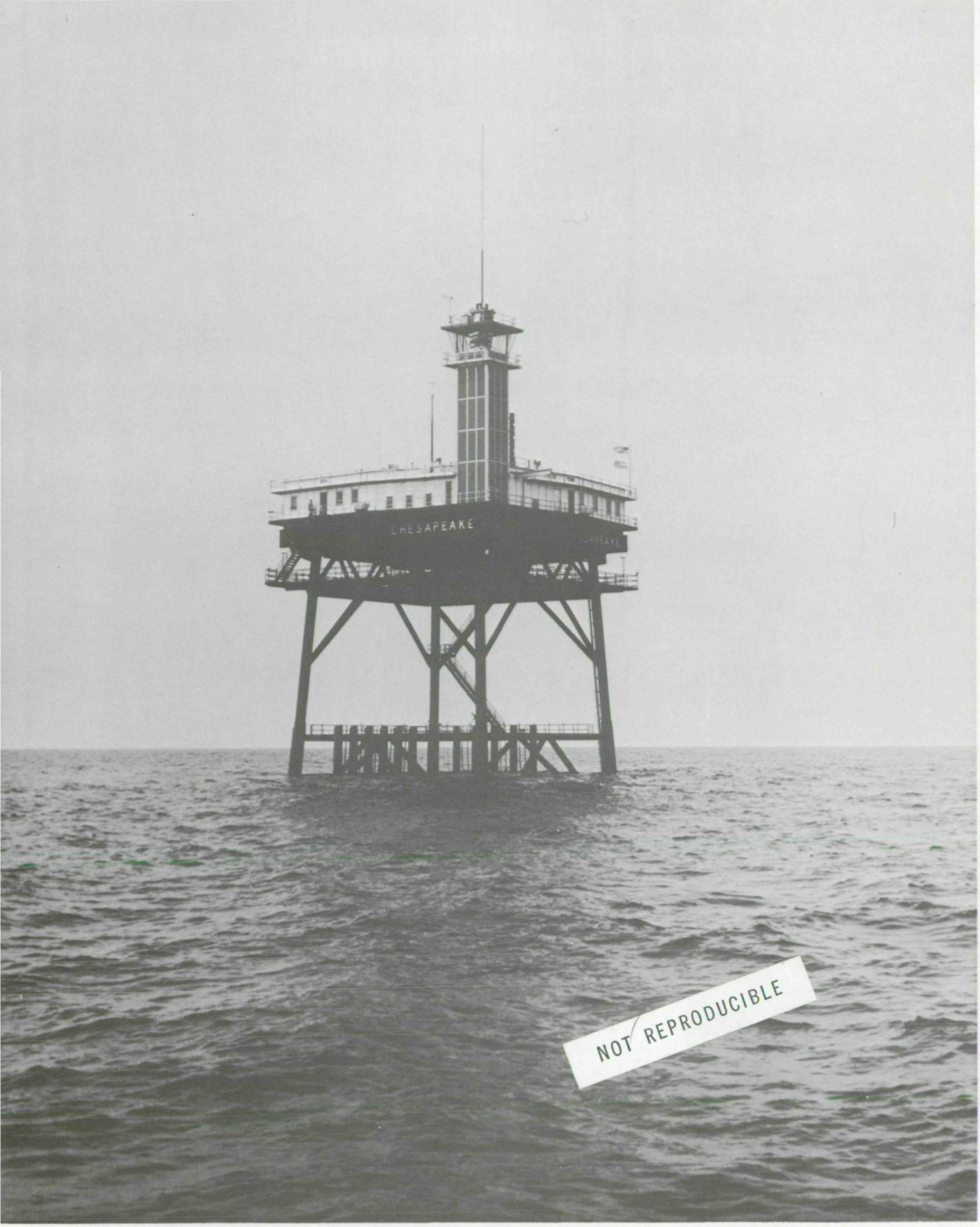


Fig. 2 Chesapeake Light Tower.

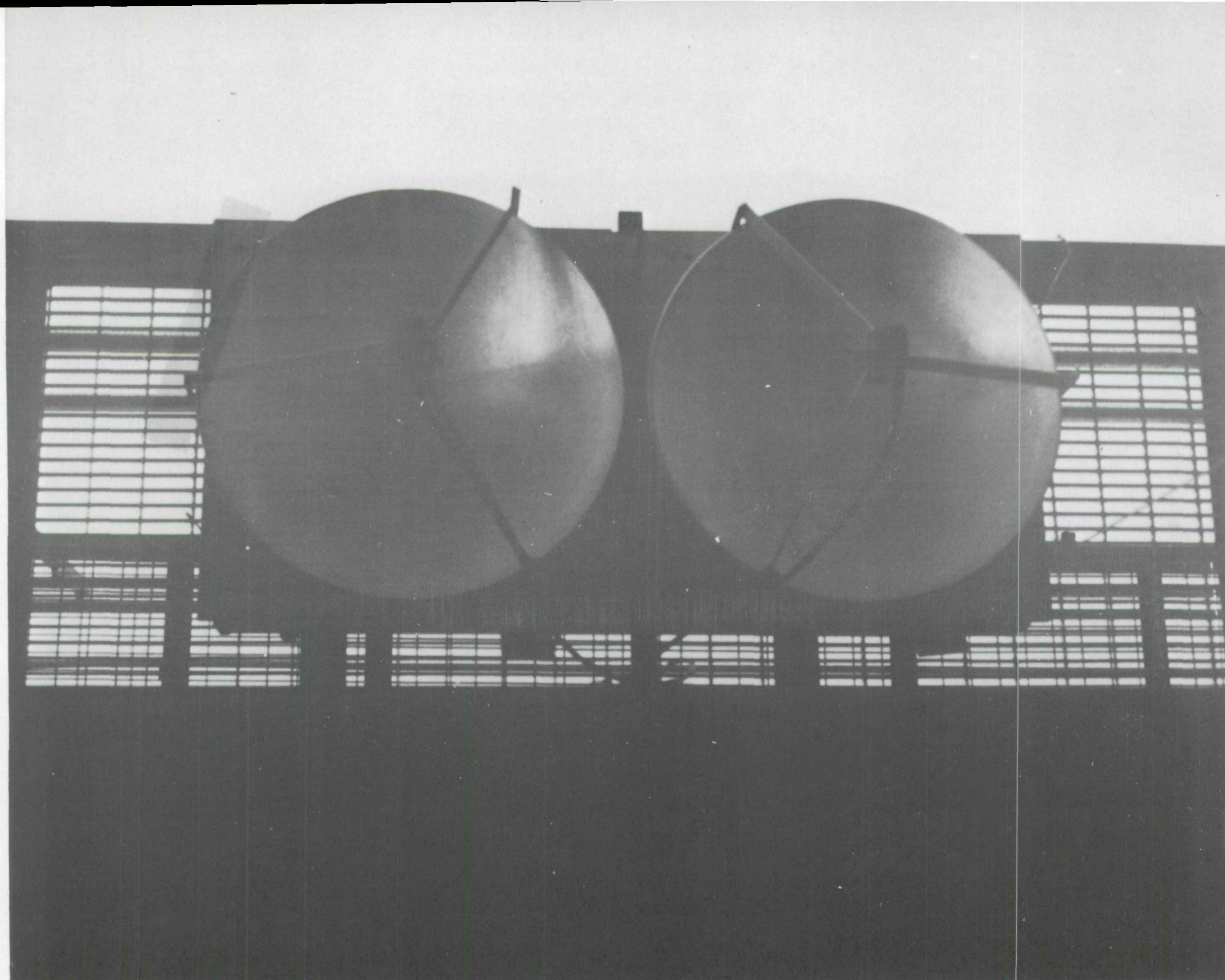


Fig. 3 Antenna Mounting on Catwalk

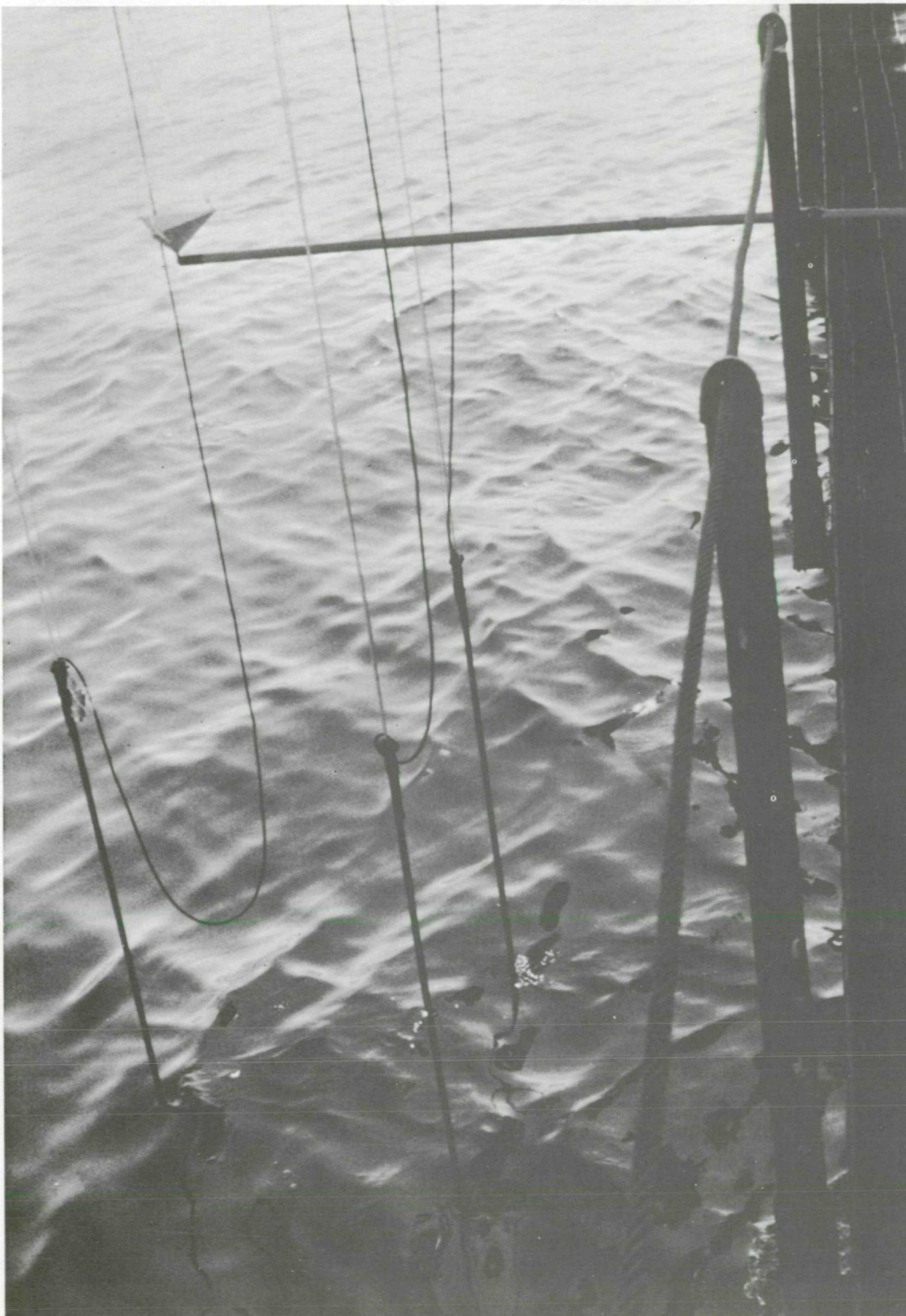


Fig. 4 Wave Pole and Corner Reflector.

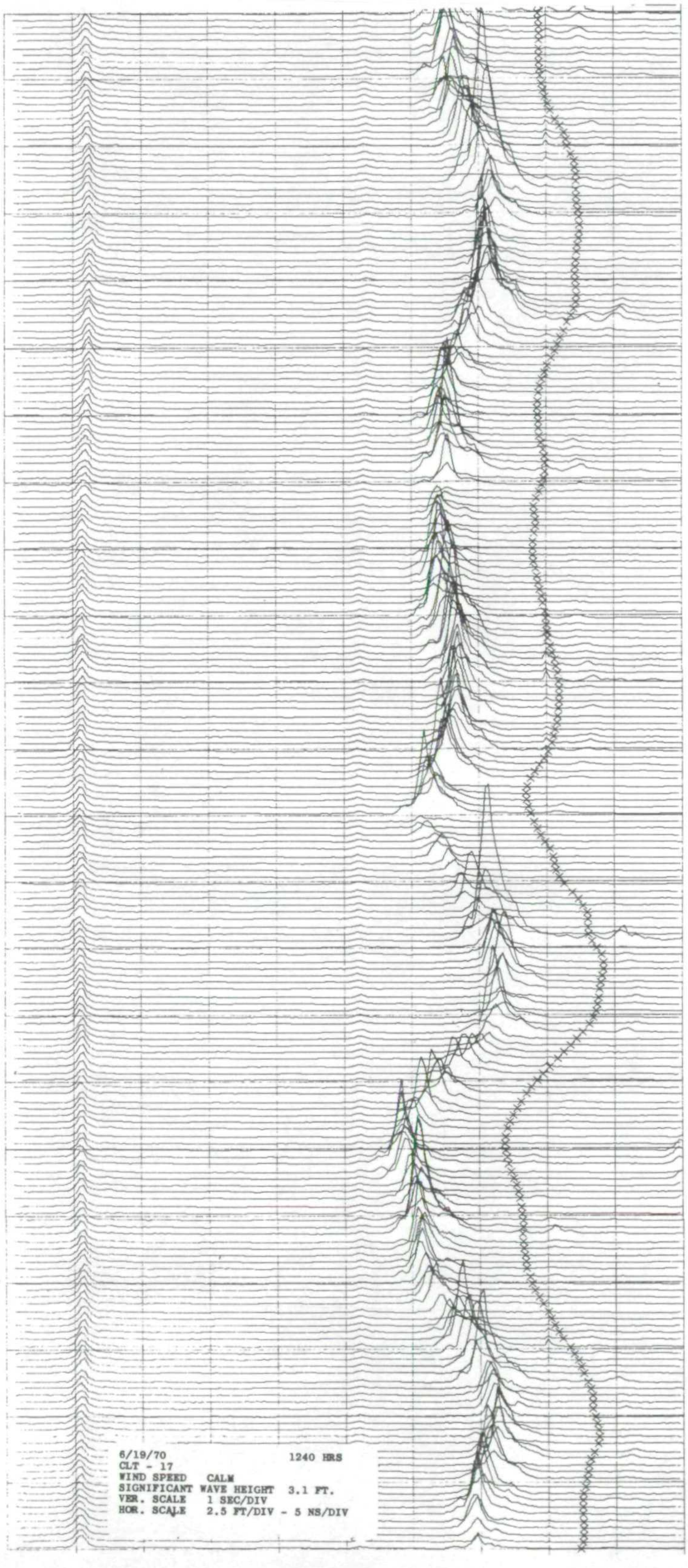


Fig. 5 Computer Plot of Radar Data

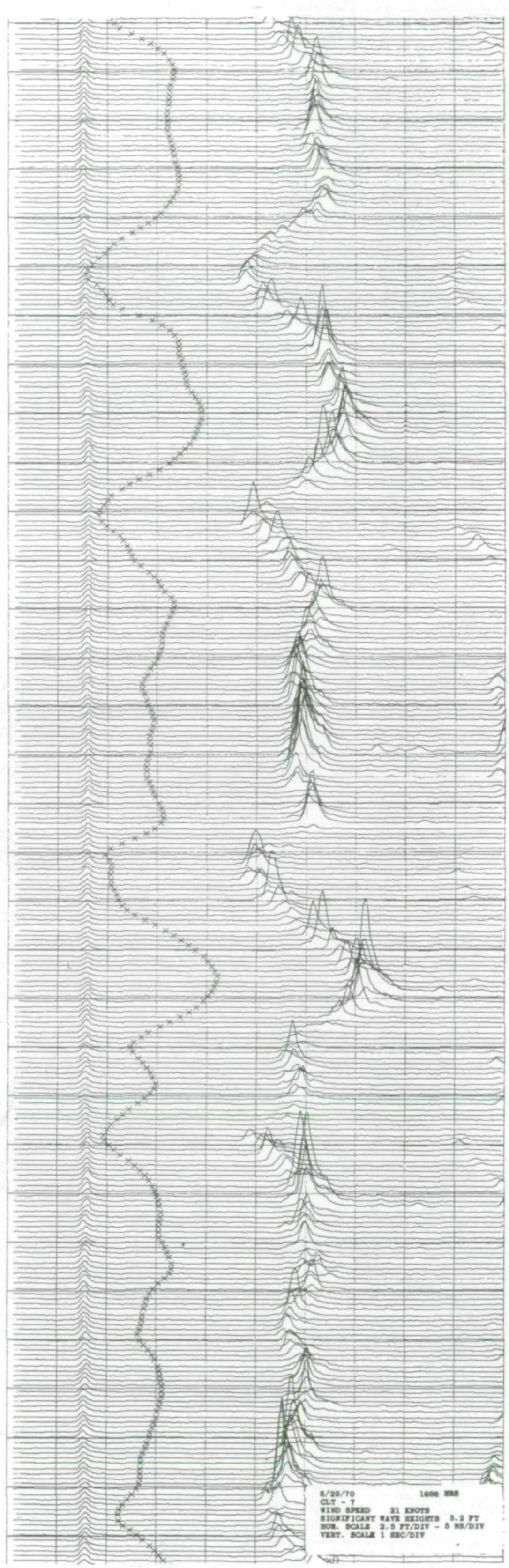


Fig. 6 Computer Plot of Radar Data

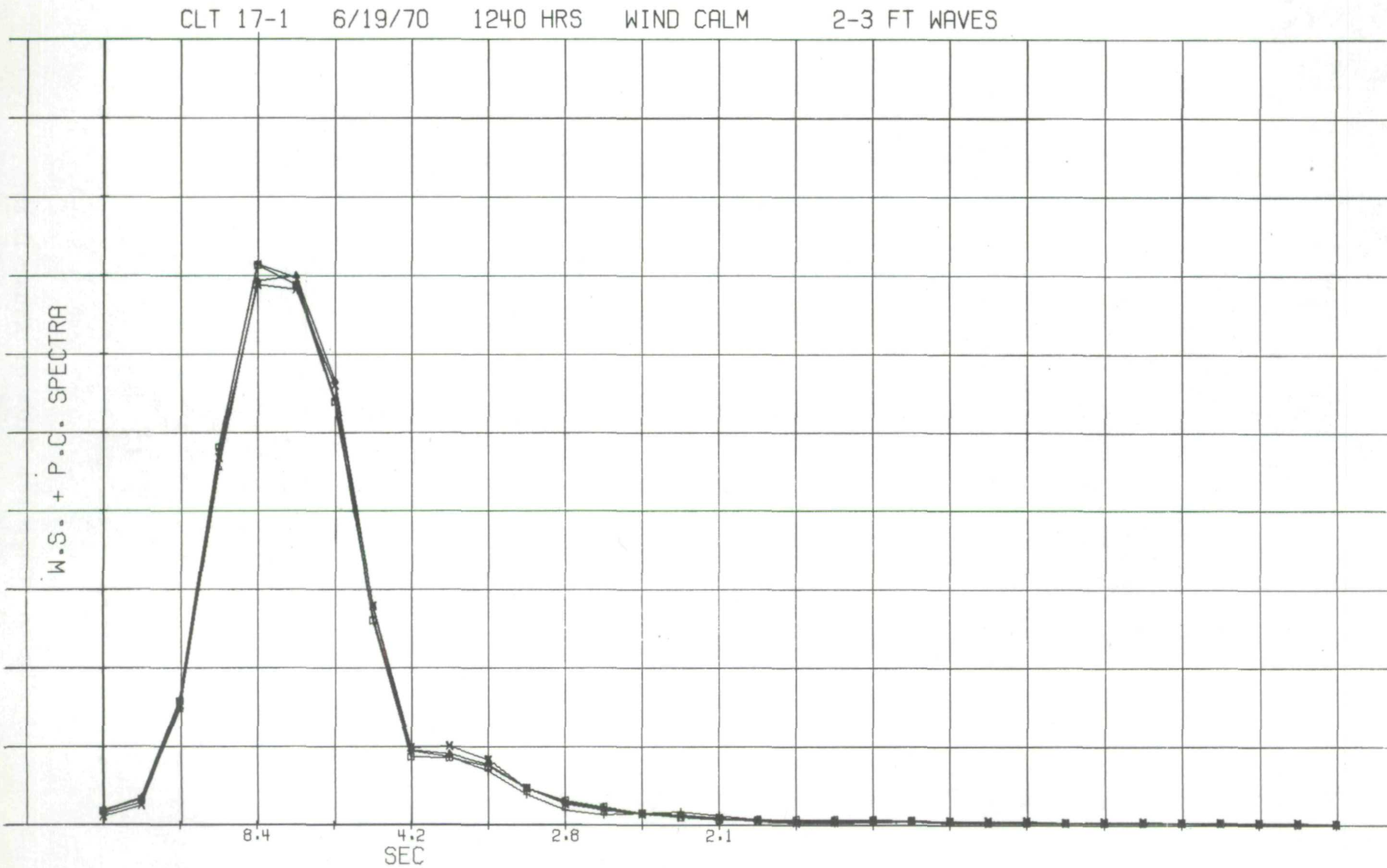


Fig. 7 Power Spectra of Radar and Wave Poles

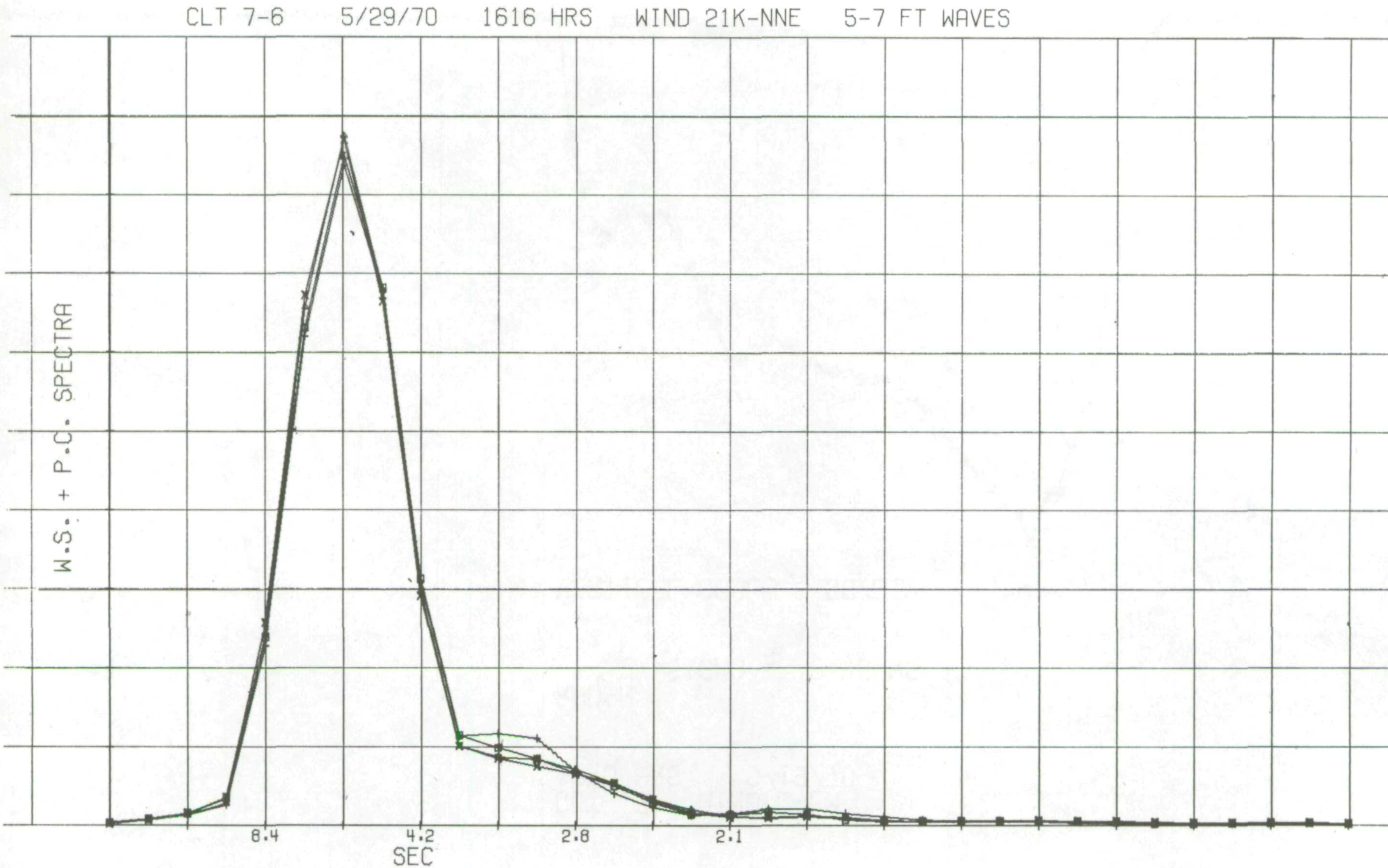


Fig. 8 Power Spectra of Radar and Wave Poles

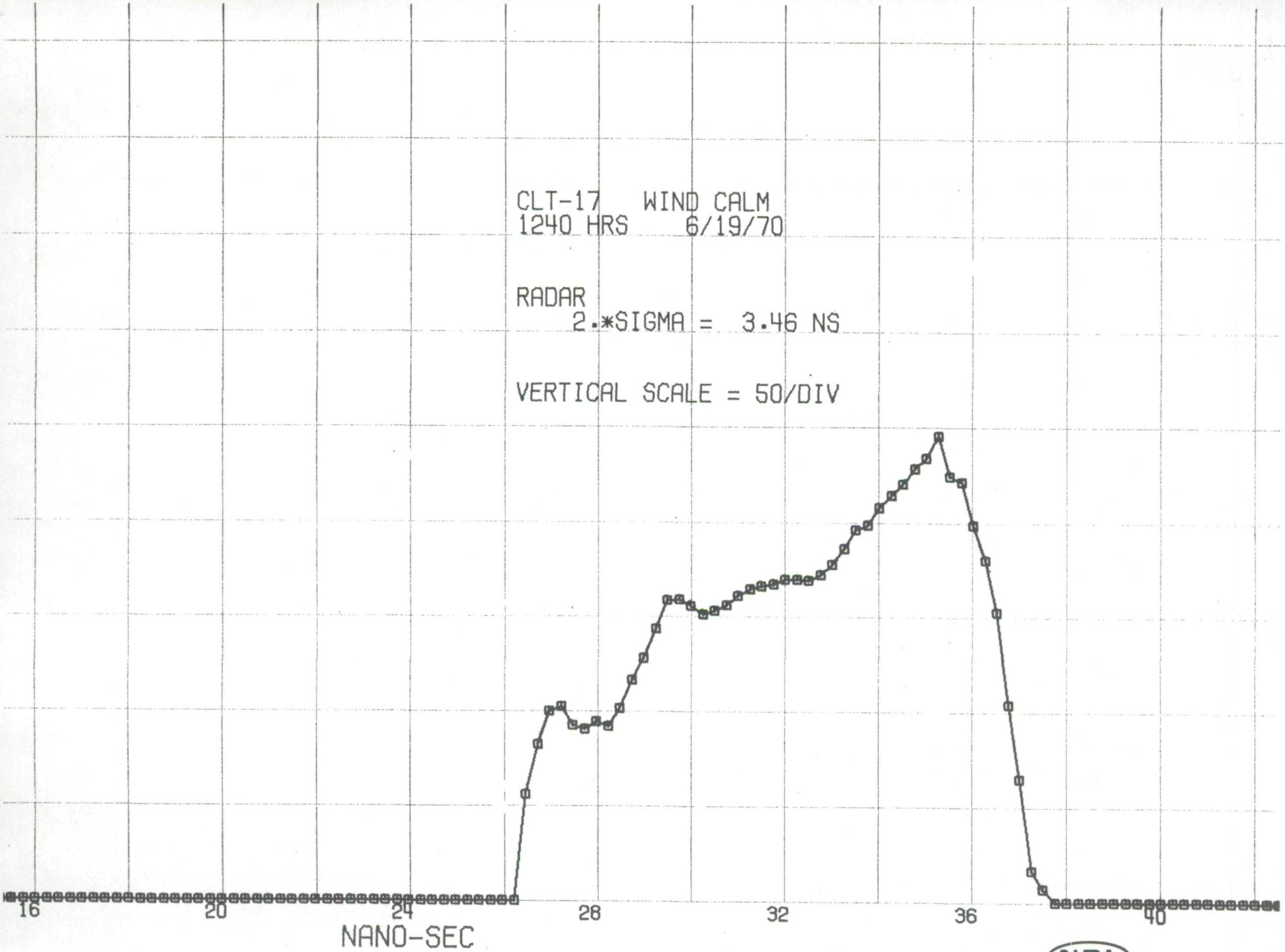


Fig. 9 Reflected Power vs Wave Depth

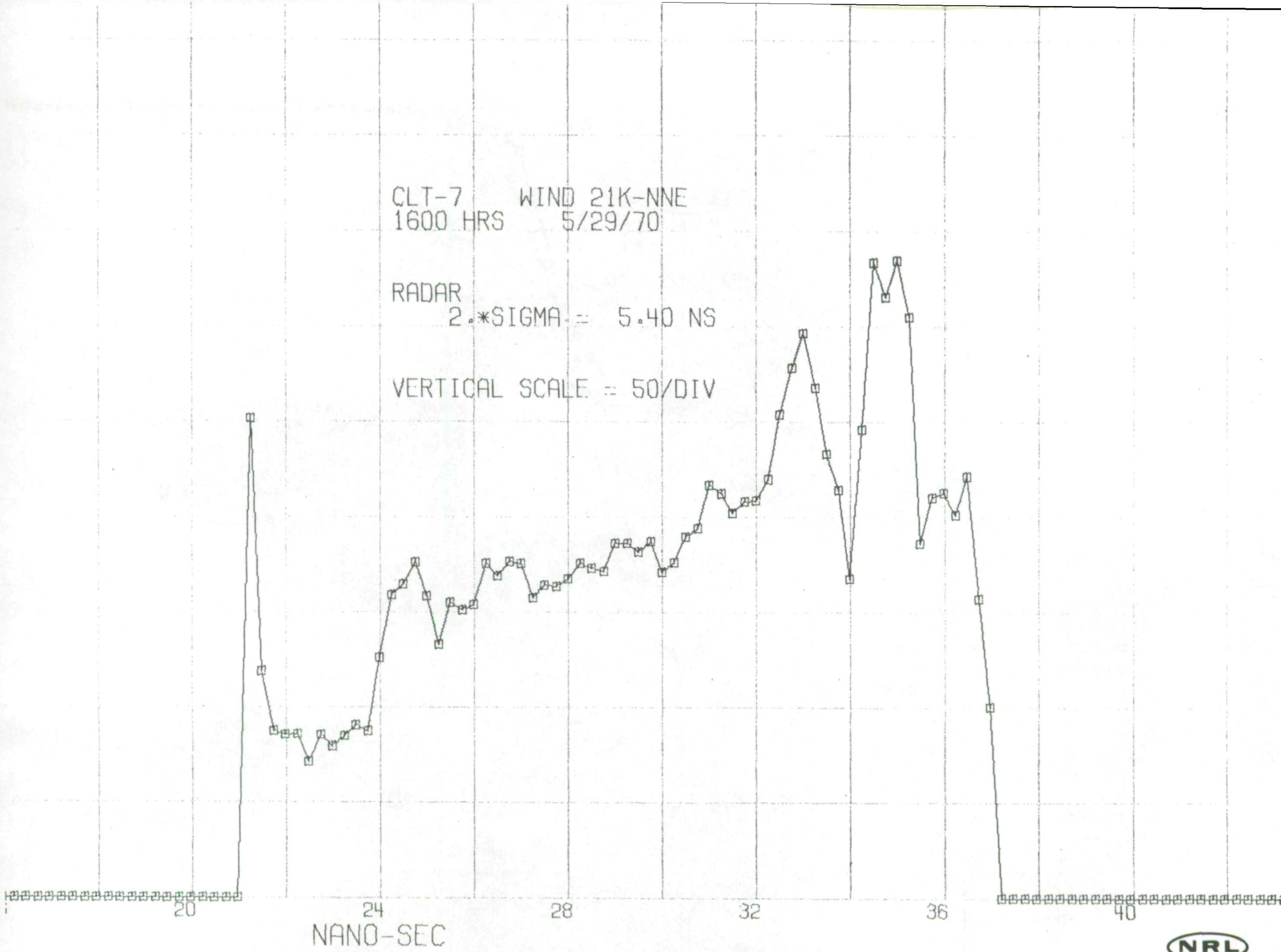


Fig. 10 Reflected Power vs Wave Depth

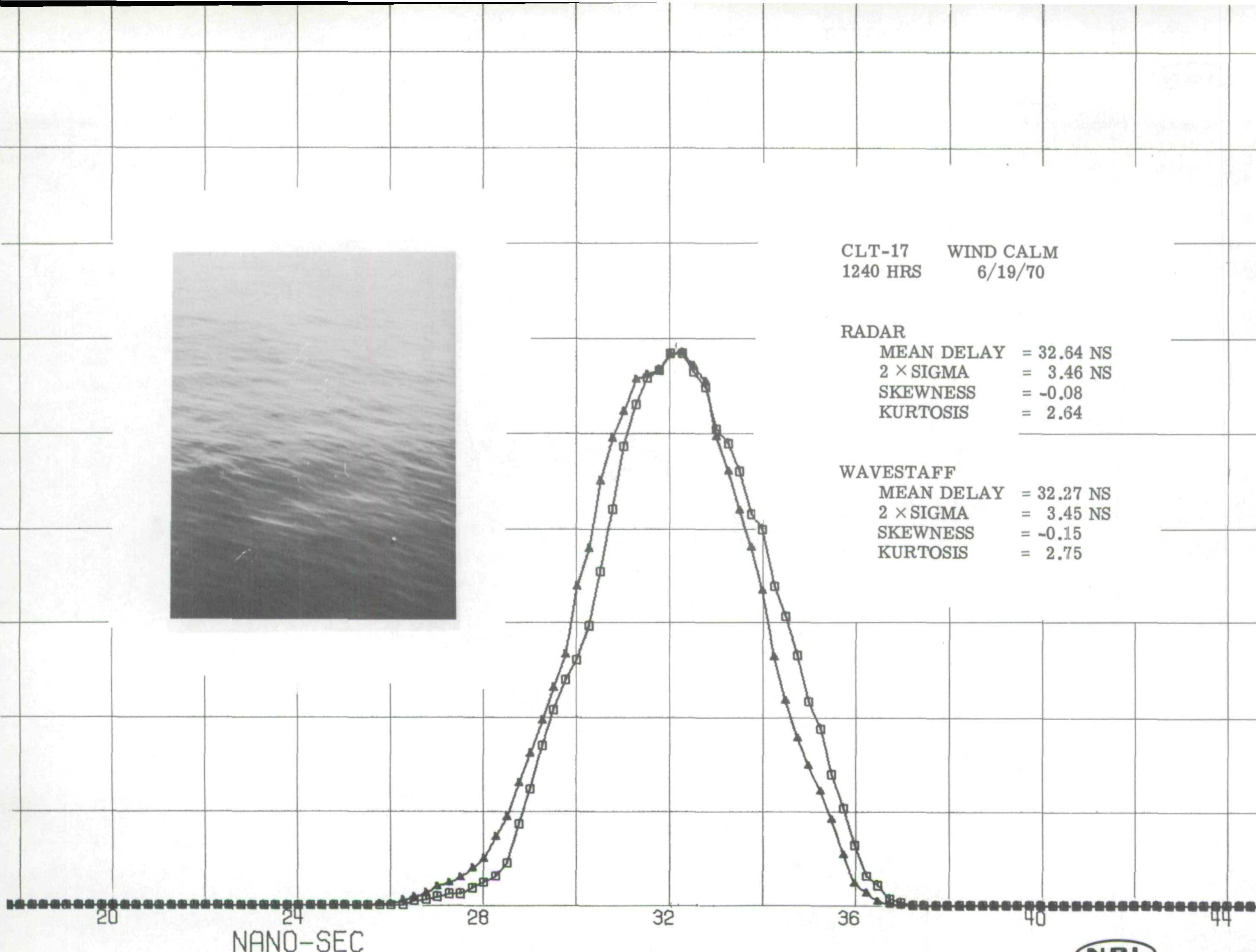
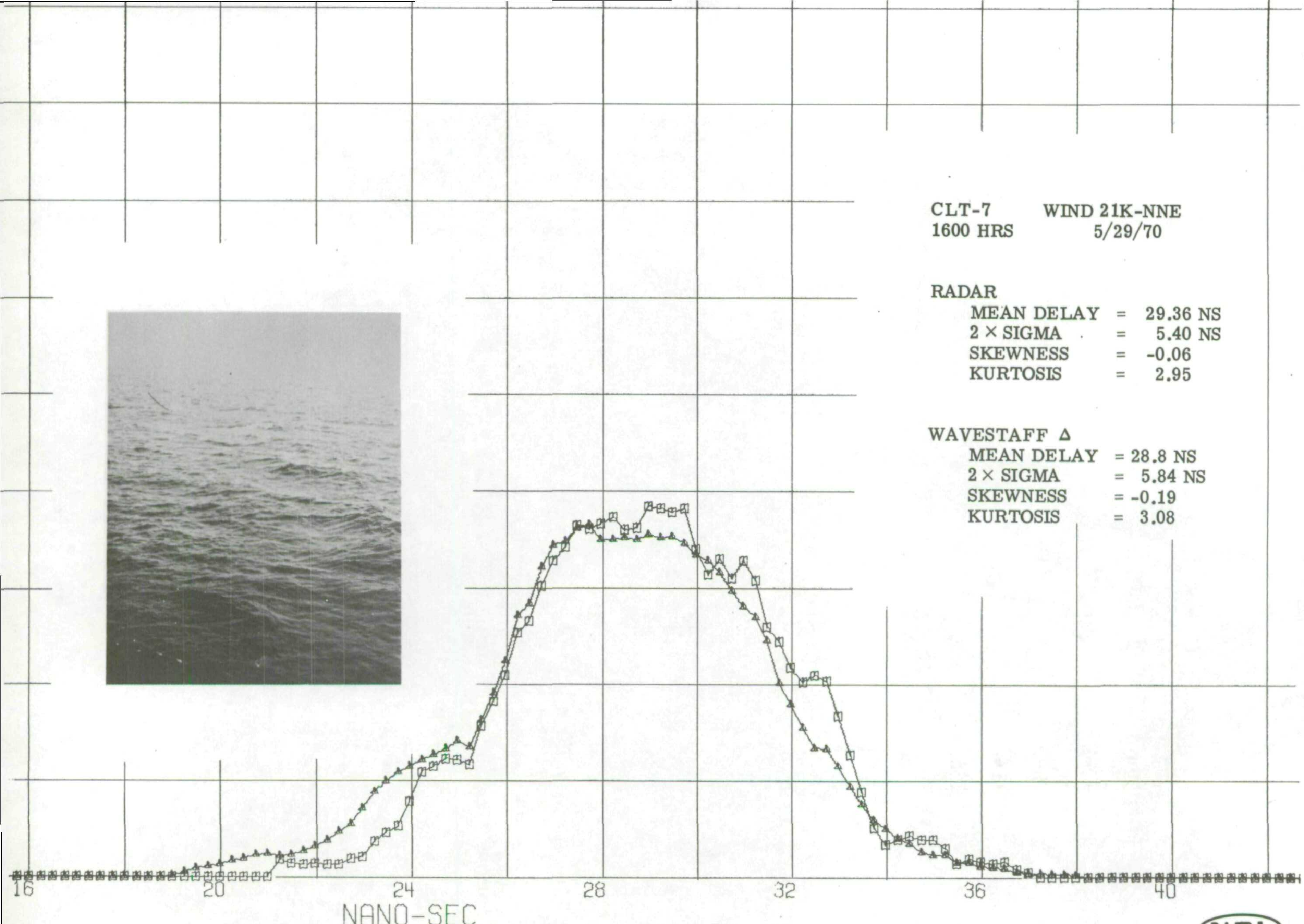


Fig. 11 Equivalent Impulse Response



NRL

Fig. 12 Equivalent Impulse Response