LOW-FREQUENCY ACOUSTIC MEASUREMENTS IN A SHALLOW-WATER AREA WITH A ROUGH SEA SURFACE

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ABSTRACT

Surface wave spectra have been measured in the North Sea simultaneously with acoustic investigations using explosive and CW sources. The goal of these experiments was to determine the influence of surface waves to low-frequency sound propagation. Vertical chains of hydrophones in different distances from the source are used to get the attenuation of the single modes. In order to resolve the influence of the surface, the experiments were carried out during different sea states. Doppler-spectra from first measurements with a 500 Hz source and one receiving hydrophone are presented.

1. Indroduction

In order to study the interaction of underwater sound with surface waves simultaneous measurments were carried out in a sea area of the North Sea, not far from the island of Sylt. Figure 1 shows the measurement area, where the water depth is about 18 m. The underwater sound is produced by explosive sound sources and continuous wave (CW) sources. From the experiment with explosive sound sources the attenuation of the primary acoustic signal is measured as a function of distance; the experiment with the CW source yields the frequency shifted sidebands. It must be pointed out, that to each of these two experiments surface wave measure-

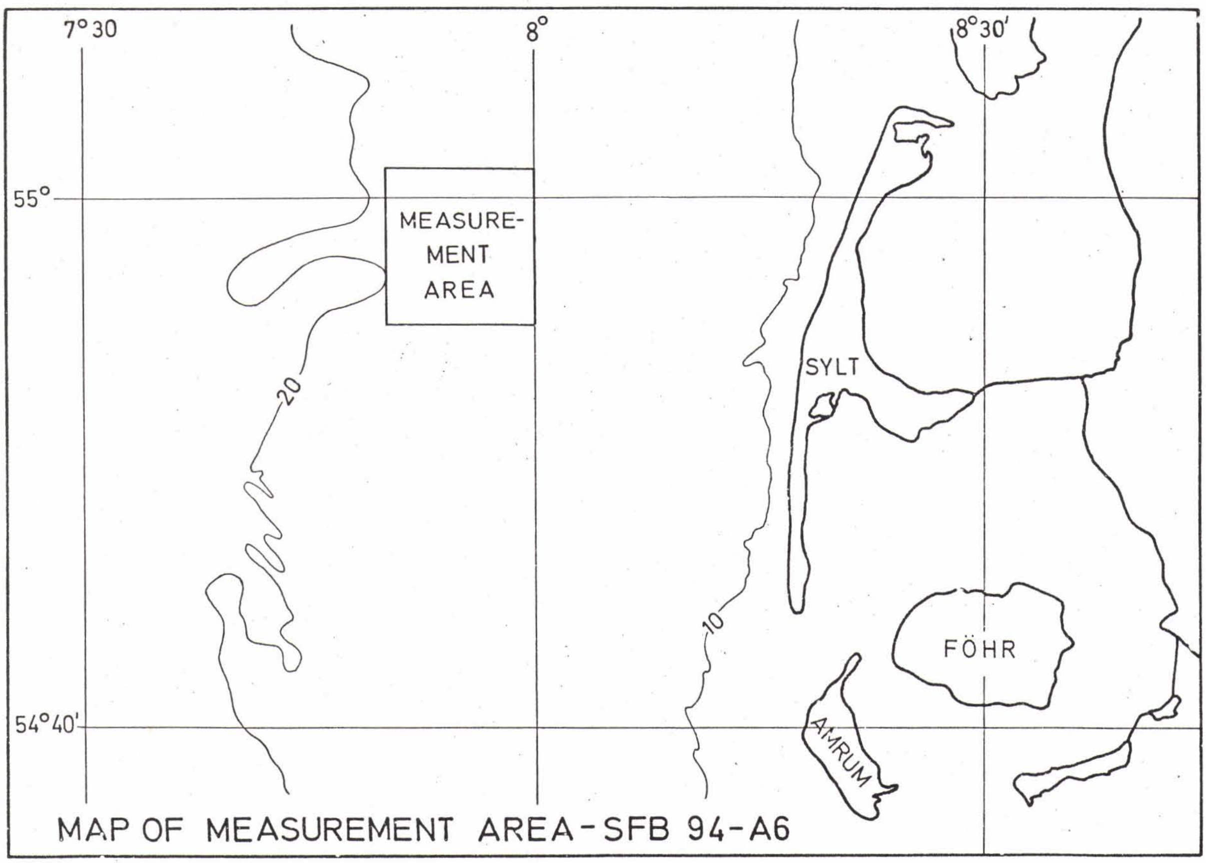

FIG. 1 MAP OF MEASUREMENT AREA NEAR THE ISLAND OF SYLT IN THE NORTH SEA

ments are carried out simultaneously. The results obtained by these methods are presented here.

2. Measurements with explosive sources

The arrangement for the explosive sound experiment is given in fig.2. The distance between the explosive sources and the first chain is 1-5 km, followed by two other chains each in a distance of 5 km. The chains are connected with a sonobuoy, which transfers the datas to the land-station. The charges detonate at a depth of 4 m; the explosion points are located at intervalls of 2oo m in line of 4 km. Three experiments are carried out at different sea states, one of these were done with only one chain in order to resolve the different modes in the shallow water. The other two experiments were carried out with three chains to resolve the modes and obtain the

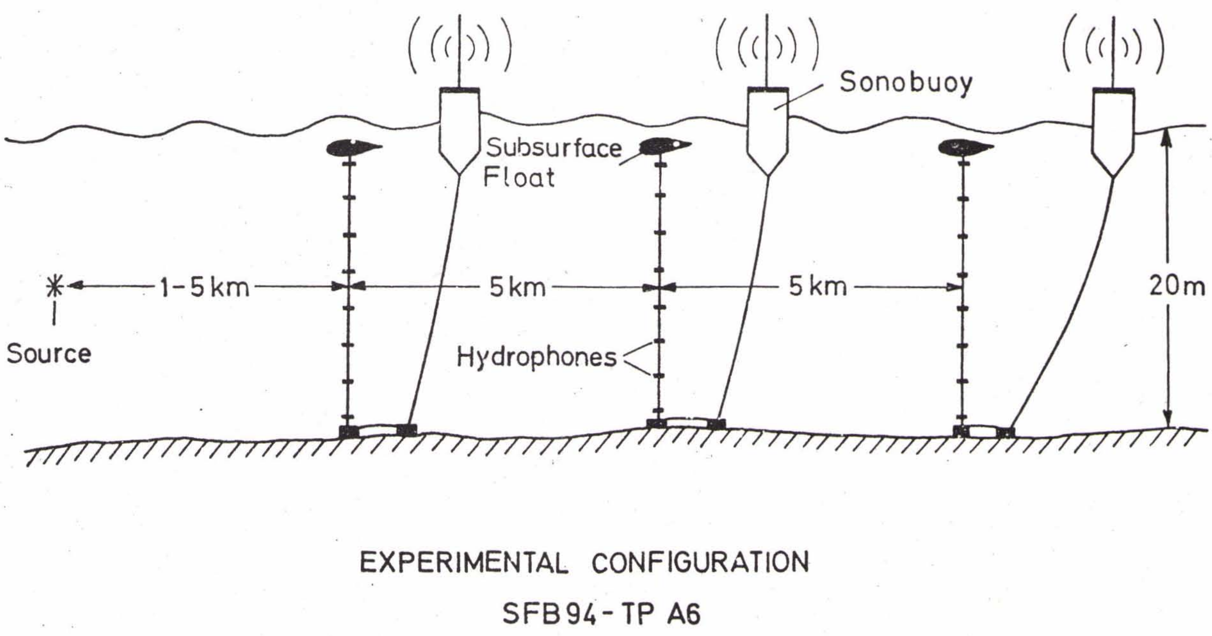

FIG. 2 SCHEMATIC ARRANGEMENT OF MEASUREMENT WITH VERTICAL CHAINS OF EIGHT HYDROPHONES AND SONOBUOYS

mode attenuation. Mode attenuation is due to reflection loss at the bottom (sediment attenuation and generation of shear waves) and scattering processes at the surface and the bottom. These effects are mode-dependent and therefore a separation of the different modes becomes necessary.

The results of the first experiment is represented in fig.3.There the original recordings of the eight hydrophones are plotted on the left side of the figure. The distance from the explosiv source was 4.1 km and the water depth was nearly constant within the range of propagation(d=18$\pm$o.5m). To resolve the different modes, the registrations are filtered with digital bandpass filters plotted on the right side of the figure.Central fre-

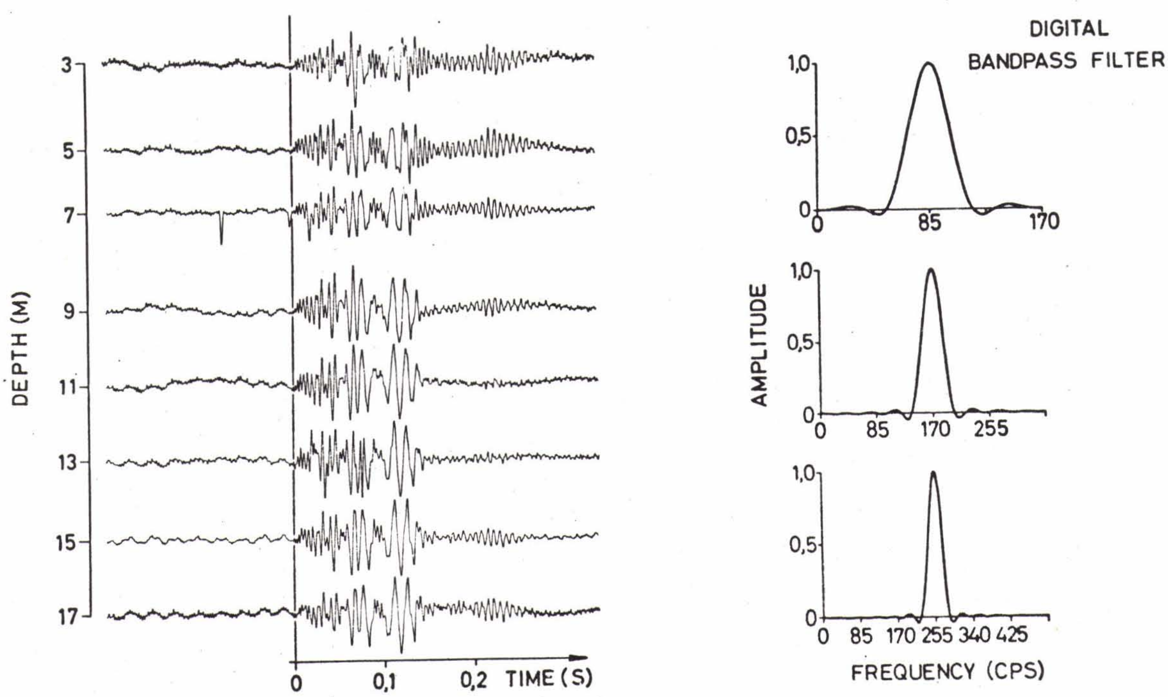

FIG. 3 LEFT: ORIGINAL RECORDINGS OF EIGHT HYDROPHONES, NORMALIZED TO SAME MAXIMUM AMPLITUDE.
RIGHT: DIGITAL BANDPASS FILTER CURVES WITH DIFFERENT CENTRAL FREQUENCIES.

quencies and bandwiths of the digital filters are obtained from computed group velocity curves for a simple two-layered wave guide model. In fig.4 the result of the filtered recordings is given. Here the positions of the

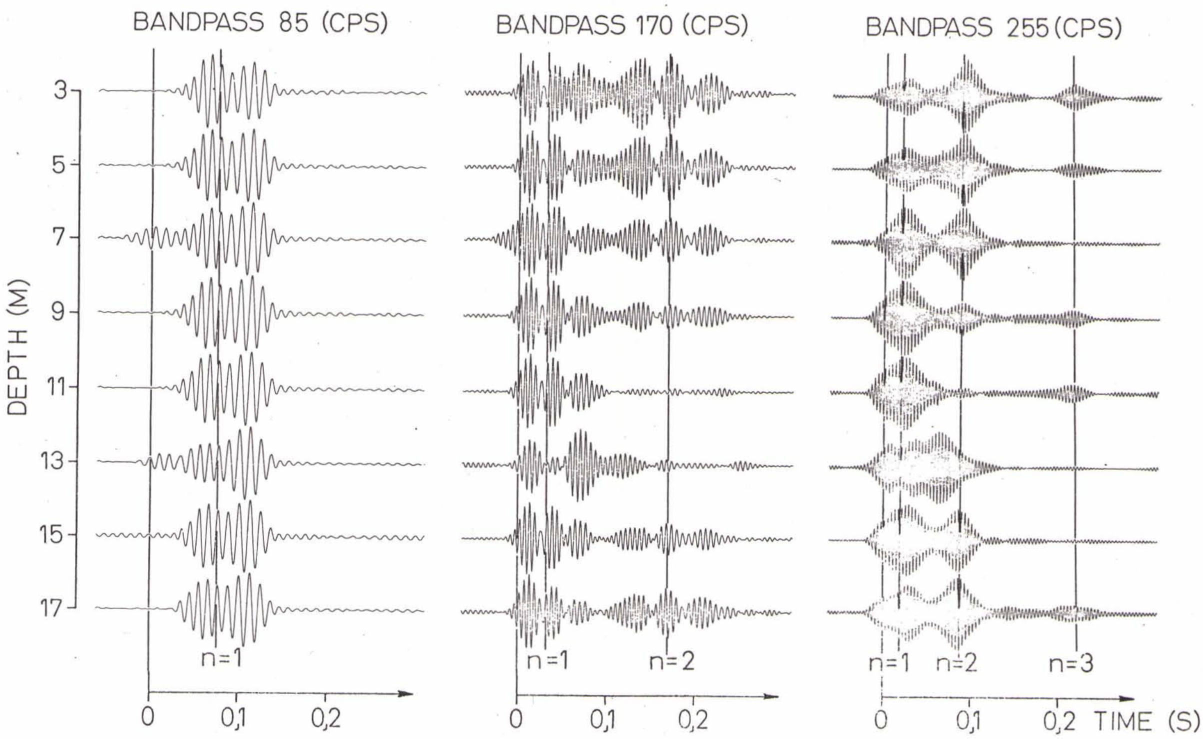

FIG. 4 BANDPASS-FILTERED RECORDINGS AT THE CENTRAL FREQUENCIES 85, 170, 255 Hz, NORMALIZED TO SAME MAXIMUM AMPLITUDE

first three modes (n=1,2,3) are marked. The splitting of wave groups belonging to one mode results from bubbles. Fig. 5 shows a more detailed analysis of the vertical amplitude functions of the modes, the computed (lines) and measured (dots) functions for the different three modes n=1,2,3. In case of the simplest two-layer model the amplitude dependence of depth is given by a sine-function. It is shown that theoretical and measured vertical amplitude function are in good agreement.

3. Measurement with a CW source

The acoustic measurement is carried out with two ships,one placed the 5oo Hz CW source at the bottom of the sea (d=18 m), the other one carried

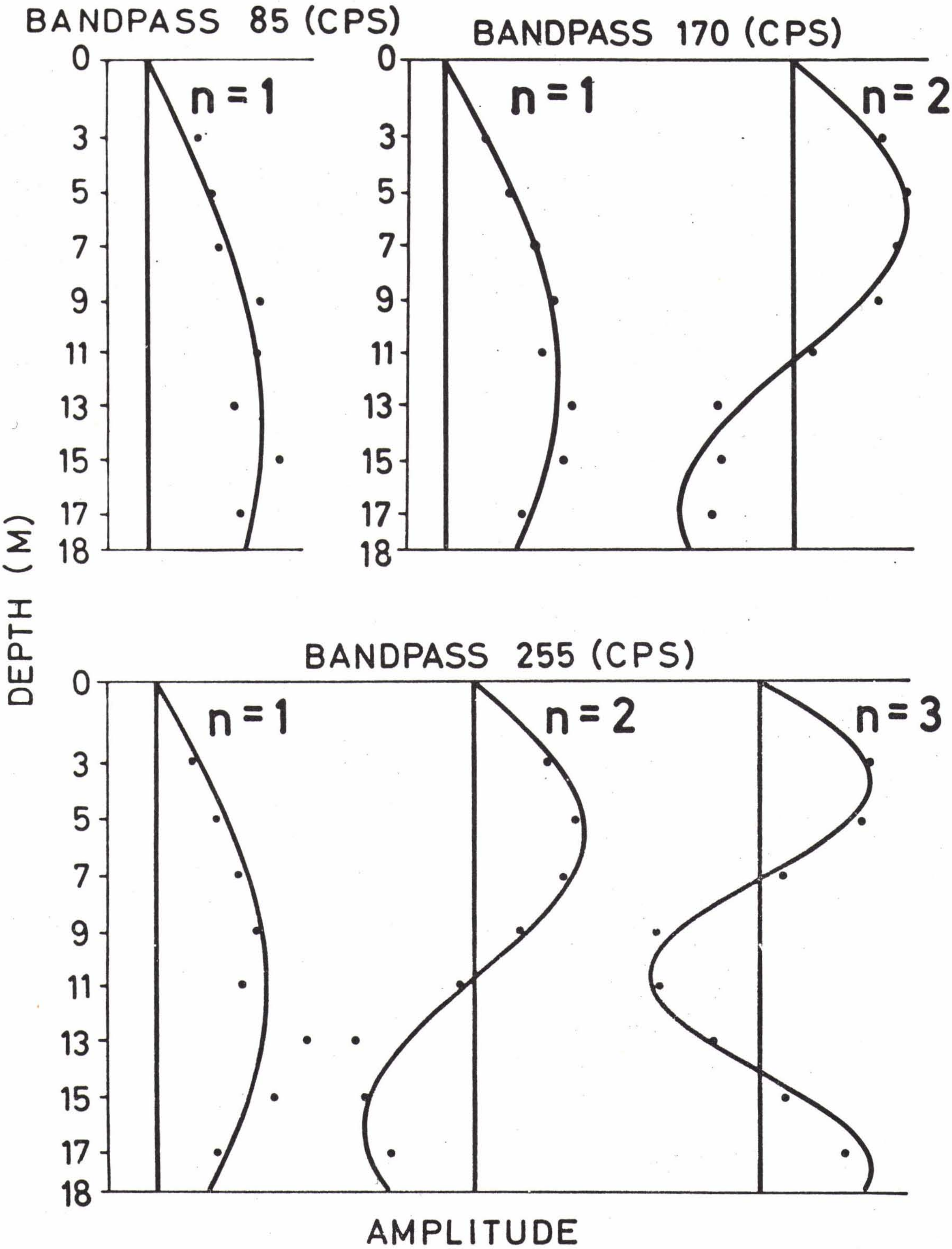

FIG. 5 THEORETICAL (Lines) AND OBSERVED (Dots) VERTICAL AMPLITUDE FUNCTIONS FOR VARIOUS MODES n , MODE AMPLITUDE IN ARBITRARY UNITS

at the same depth a hydrophone (see fig.6). The distance between the ships is about 6 km. On one hand the 5oo Hz signal is transmitted through the water, on the other hand a registration by radio circuit is

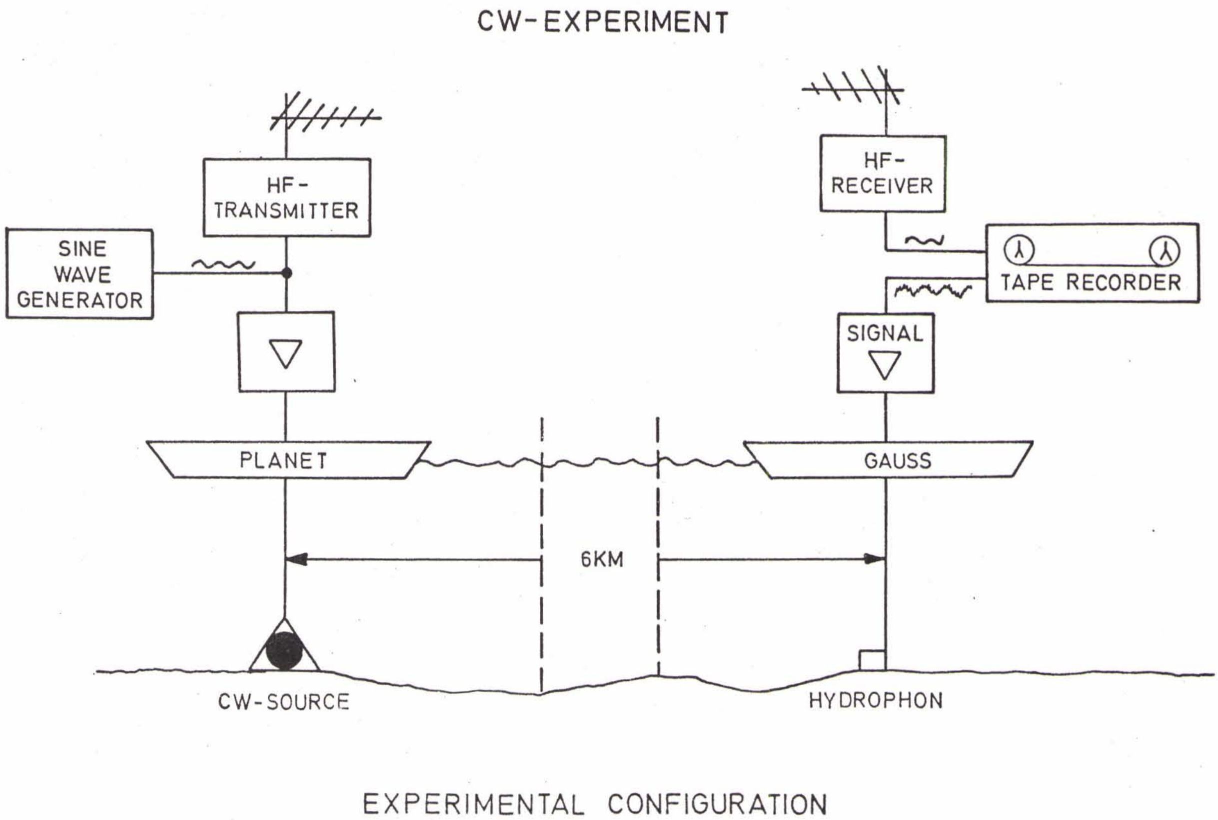

FIG. 6 EXPERIMENTAL ARRANGEMENT OF THE CONTINUOUS WAVE (CW) EXPERIMENT

performed. Both the HF signal and the signal of the hydrophone are registrated on a tape recorder. Simultaneously surface wave measurements with a wave rider buoy are carried out. The acoustic signal is modulated by the surface waves and is disturbed in amplitude and phase, whereas the HF signal is undisturbed. By a special procedure, called "phase coherent demodulation " the received acoustic signal is separated from the 5oo Hz carrier frequency. As result we get the disturbed signal. This signal includes the frequencies of the surface waves. From time series with a length of 3o min. power spectra are computed. These spectra are compared with the power spectra we received from the direct measurements with the wave-rider buoy. The results are shown in fig.7. The amplitudes at the peaks of the two power spectra are different. Both peaks (swell at o.13 Hz and wind waves at o.28 Hz) are found at the same positions, however, the acoustic spectrum of the wind wave peak is decreased in comparison to the direct surface-wave measurements. Theoretical considerations using the Bragg-scattering are carried out and shows a good agreement with some characteristics of the measured data. A more detailed study of this point cannot be given here.

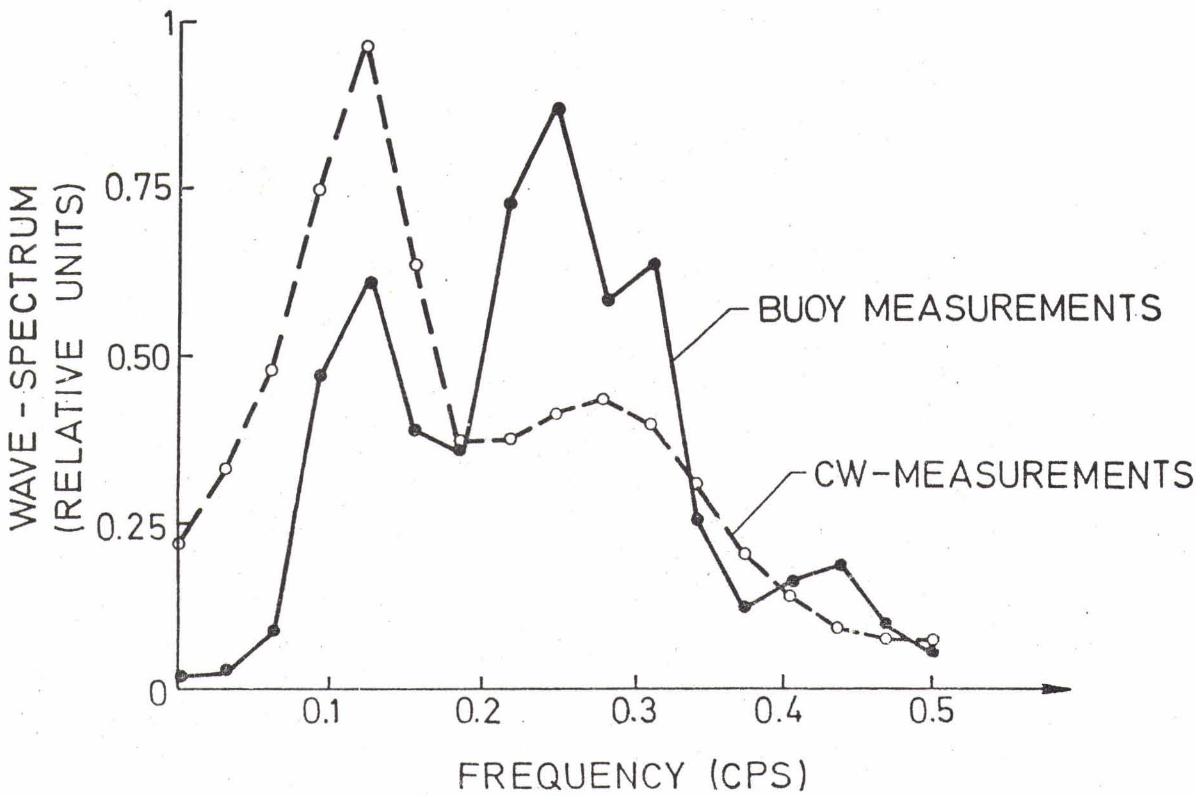

FIG. 7 POWER SPECTRA OF SURFACE WAVES
——— MEASURED WITH A WAVE-RIDER BUOY
– – – MEASURED WITH A CW SOURCE

4. References

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