DIRECTIONAL ECHO SOUNDING

by H. F. P. Herdman

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SUMMARY

A short account of an experiment to improve the directional quality of deep water echo sounding equipment. A comparison is made between the results obtained with the pre-war sonic deep water echo sounding set then fitted, and the present-day supersonic type of equipment now installed in the R.R.S. *Discovery II*. Methods of stabilizing the transmitter and receiver to overcome the effect of rolling on the narrower and, hence, more directional beam of sound now transmitted, are discussed. A short description of the method adopted is followed by particulars on an attempt to increase the amount of energy transmitted, by a reduction in thickness of the hull plating, in way of the stabilized transmitter and receiver.

Experiments are now being made in the R.R.S. *Discovery II* in an attempt to improve not only the directional quality of the deep-water echo-sounding equipment but also the strength of transmission and reception. Before describing these experiments — which are being made in collaboration with Messrs. Kelvin & Hughes — mention should be made of the different types of deep water equipment which have been, and are now fitted. In addition some comparison should be made between the performance of the sonic deep-water equipment carried until the outbreak of war in 1939, and that of the supersonic magneto-striction type of apparatus by which it has been superseded.

The original deep-water echo-sounder installed in the *Discovery II* in 1929 was the British Admiralty Deep-Sea Pattern, made by H. Hughes & Son. This was a sonic instrument of the listening type, operating at a frequency of 2,000 cycles/sec. Transmissions were effected by a compressed air-powered hammer which struck a diaphragm mounted on a water tank secured to the hull and the receiving hydrophone was fitted externally through a sluice valve. Between 1930 and 1932 we obtained with this apparatus a number of soundings greater than 4,000 fm (7,315 m) in the South Sandwich Trench. The greatest corrected depth recorded was 4,480 fm (8,193 m). In 1933 the listening-type receiver was supplemented by an « Acadia » type electrolytic recorder with a phasing system operating to any depth by 100 fathom steps. Apart from replacements due to fair wear and tear, this equipment was in constant use until the outbreak of war in 1939. Shortly afterwards it was removed and scrapped.

When the *Discovery II* was recommissioned as a research vessel in 1950, and since the original type of deep-water echo-sounder was no longer made, a Kelvin & Hughes Type 21 E echo-sounder was fitted. This is a magnetostriction type, operating at a frequency of 10 kc/sec., and recording electrolytically on paper in fathoms, or fathoms × 10. More recently another recorder has been added, which records on metallized paper (« Teledeltos » recording). Transmitter and receiver were both fitted in tanks *inside* the shell plating (0.43" thick, at the positions concerned). Theoretically, the depth-range is unlimited — in practice, the greatest depth recorded so far has been 3,733 fm (6,827 m). It is only fair, though, to add that, since this new set was fitted, the ship has only passed over such very deep water on one brief occasion — when crossing the South Sandwich Trench in very poor sounding weather, during work on the Antarctic ice-edge in the winter of 1951.

With sonic equipment — where a hammer strikes a plate in contact with the sea — the sound-waves are projected with a considerable amount of « spread »; observations made during survey work indicated that the semi-angle of spread might be roughly 45°, but the weakness of the « fringe » echoes supports the theory that, for this particular hammer, the greater part of the transmitted sound was projected towards the bottom (Herdman, 1948). The magnetostriction, or supersonic set, fitted in 1950, transmits a more compact beam, or rather, cone of sound, in which the energy falls to half value at an angle of 8° to the axis, and is zero at 21°.

With the original sonic deep-water set the rolling of the ship — unless sufficiently vigorous to set up interference in the microphone or cause water-noises, which masked the echo — was not a serious hindrance to recording echoes. As already mentioned the spread of the transmission was considerable and the angle at which the returning sound waves struck the face of the hydrophone was not very critical. If the sea-bed was level echoes recorded under these conditions were probably the true depth but — if the bottom was distinctly irregular then — as the strongest echo (normally taken as the sounding) was almost certainly returning from the nearest point — which might or might not be directly under the ship — the contour of the bottom shown on the record was probably not truly representative. The echoes received from the more-directional transmissions of the present-day supersonic equipment certainly give a more correct record of the shape of the bottom, but there are disadvantages. In the first instance, when sounding up (or down) a steep slope there is, assuming specular reflexion, the danger that, if the slope angle is greater than the semi-angle of spread of the transmissions, the echo will not be received.

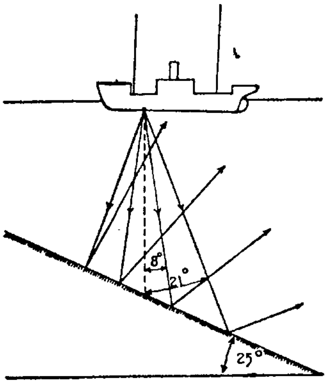

Fig. 1.

Diagrammatic representation of sounding up a steep slope

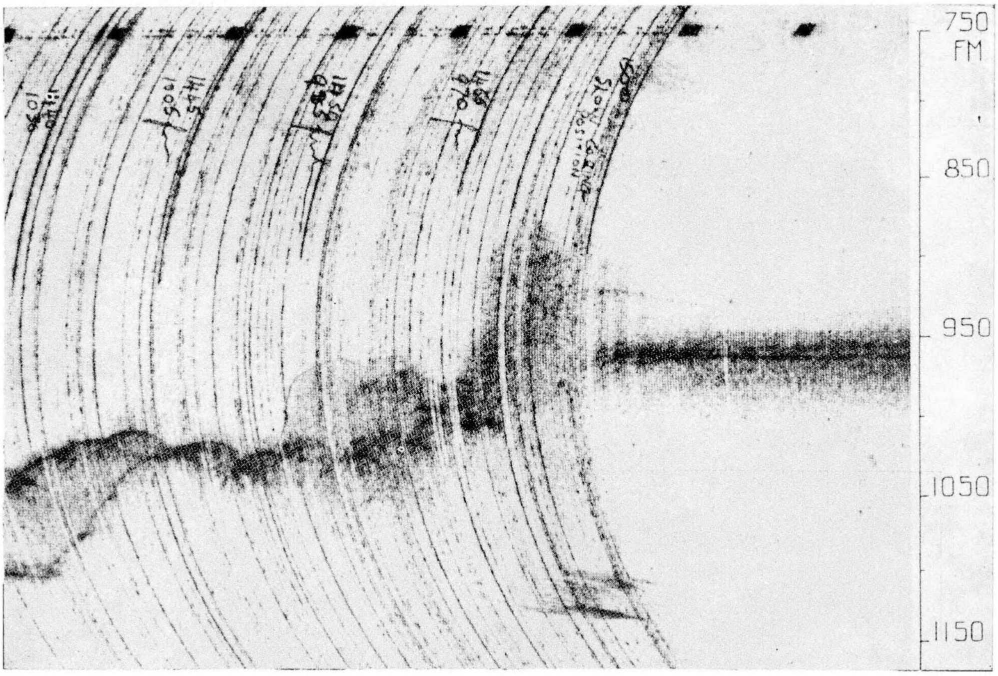

Fig. 2.
Echo-trace approaching, and at beginning of Station 3121

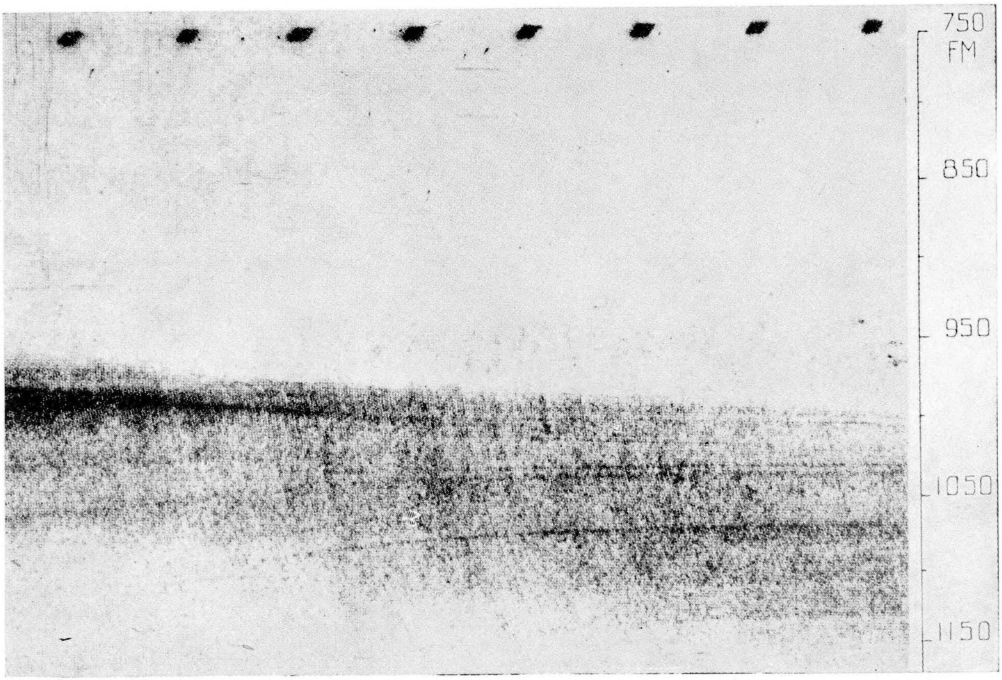

Fig. 3.
Echo-trace with ship hove-to on Station 3121 (wind 280° (true), force 4 (11-16 km.), sea 280° (true) - height 2-3 ft.)

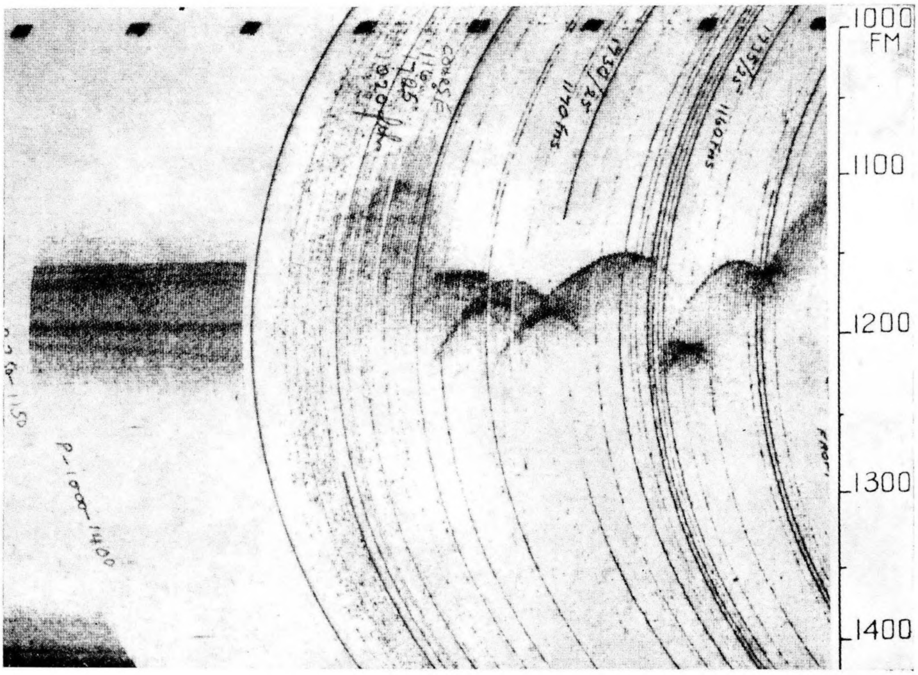

Fig. 4.
Echo-trace at end of Station 3121, and when under way after station

In practice, however, a number of echoes are received; some faint, probably from transmissions beyond the normally effective angle of spread; others stronger, probably from irregularities in the surface of the slope. Under these conditions lengthening of the echo-trace is often observed.

Another instance of the effect of spread is shown in Fig. 2, 3 and 4 — which comprise 3 sections of a recording made at depths between 975 and 1,175 fathoms (corrected), on the Mid-Atlantic Ridge, in June, 1954, with the ship hove-to on Station 3121 (1). The bottom here is very diverse in character and it will be clearly seen that it is quite impossible to say which echo-trace represents the true depth directly under the ship.

A more serious disadvantage of the reduction of spread of the transmissions is the effect set up by the movement of a small ship, especially when the ship is rolling. Even in moderate weather a ship constructed on the lines of the *Discovery II* will roll extensively and thus there are the possibilities either that the transmissions may be directed well off the direct path to the bottom, so that the returning echo misses the receiver or, if the transmissions were made with the ship on an even keel that, by the time the echoes return, the ship may have rolled to an extent that the signals will arrive at the receiver when the latter is at such an angle that it is insensitive to them.

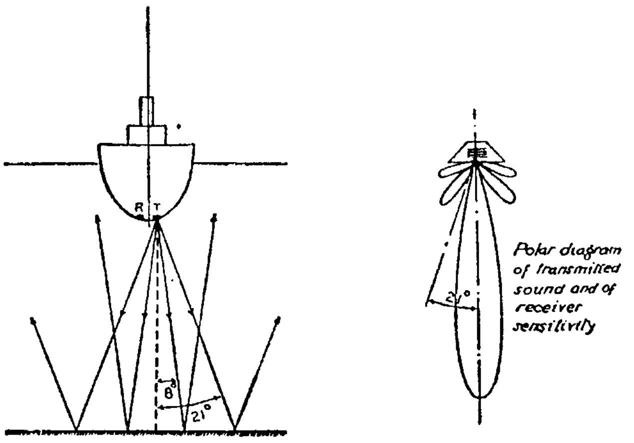

Fig. 5 (a)

Diagrammetic representation of sounding with ship on an aven keel

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(1) Stations in the *Discovery II* are worked normally with the ship hove-to head to wind and, so far as is possible, making no headway through the water Nevertheless, if there is any appreciable current or drift in the surface layer, there will be a comparable movement of the ship over the bottom which will, when the bottom is very irregular, show markedly on the echo-trace.

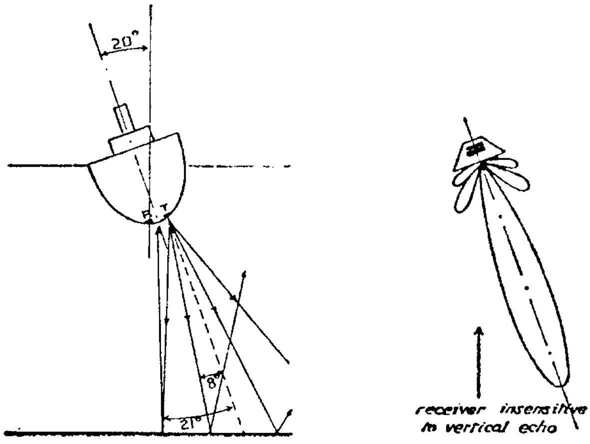

Fig. 5 (b)

Diagrammatic representation of sounding when ship is rolling 20° from vertical

If the narrow, directional beam of transmission is to be retained — and this is most desirable — then stabilization of both transmitter and receiver to the roll of the ship would seem to be the solution. The effect of pitching can be ignored as when a ship is pitching heavily in a head sea, so much aeration is set up under the hull forward (where the transmitter and receiver normally are fitted) that not only are the echoes obscured by air-bubbles and water-noise, but the outgoing sound-waves are themselves blanketed. In any event, compensation for pitching would not have been practicable in the *Discovery II* without major structural alterations which were unlikely to be approved by Lloyd's Register of Shipping.

Three methods of stabilizing the transmitter and receiver for athwartships motion were considered during the refit of the ship in 1953-4; two of these implied control of the movement, the other did not.

The methods were : (1) gyroscopic control, (2) control by electronic methods and, (3) the simple but uncontrolled method of mounting the reflectors so that they could swing freely in the athwartships line. Whereas methods (1) and (2) would have controlled the movement of the transmitter and receiver accurately, not only was the cost of providing such equipment likely to have been heavy, but there would have been considerable delay in making it and fitting it in the ship. On the other hand the alterations required, if the third method was adopted, were not extensive and the equipment could almost certainly be ready for trials on completion of the refit. A disadvantage of this method would be, of course, the probable lag in the swing of the oscillators; this was, however, not expected to exceed 5° (much less than the degree of roll for which compensation was desired) and thus, in view of the very much experimental nature of the trials, could be accepted.

Method (3) was therefore adopted and, as shown in Fig. 6, a pair of type 21 E oscillators (exactly similar to those already fitted in the normal way) were mounted in two special watertight tanks, constructed by isolating part of the forward double-bottom fresh-water tanks to port and starboard of the centre line, 3 ft. 7 in. forward of the existing oscillators. Arrangements were also made to ensure that the oscillator tanks were kept absolutely full of water.

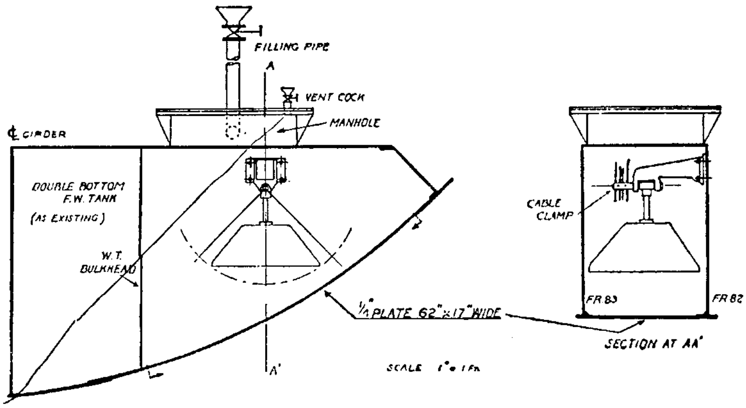

Fig. 6.
General arrangement of stabilized oscillators - as fitted in double-bottom tanks

The existing Type 21 E fixed transmitter and the stabilized instrument now fitted were connected, via a change-over switch, to a common transmission unit. The two receivers were similarly connected — through a separate switch — to the 21 E and 26 E recorders. Comparison of the two systems could not, therefore, be made simultaneously on two recorders but as weather conditions and the state of the sea do not usually alter in a matter of seconds, little information of interest was lost. The superiority of the stabilized system was markedly shown on most occasions when the ship was rolling moderately; the echo-trace was almost continuous and considerably less gain was required to give the same intensity of echo-marking as recorded with the fixed oscillators.

Both the fixed and stabilized oscillators in the *Discovery II* have been transmitting and receiving through the full thickness of the hull plating (0.43" or 10-9 mm), with a consequent and — probably considerable — loss of energy. The ratio of thickness of hull plating to the wavelength in the steel of the plating is a very important factor in echo-sounding; it must be kept as small as possible consistent with the requirements of safety, and a plate thickness of 0.25" (6.35 mm) is recommended by Messrs. Kelvin & Hughes for a standard installation. Permission was sought therefore from Lloyd's Register of Shipping for a reduction in thickness of the hull plating in way of the stabilized oscillator compartments. Subject to certain safeguards, approval to fit plating 0.25" (6.35 mm) thick was obtained, and an area of the original hull plating in each tank, 62" × 17" (1.57 × 0.43 m), has recently been cut out and replaced by the thinner plating — welded flush with the outer side of the original plating. All external laps in way of the stabilized compartments have also been faired by welding.

Owing to certain technical difficulties arising from the special construction of the *Discovery II*, it was not practicable at the same time to arrange for plating of the same thickness to be fitted under the standard tanks of the original Type 21 E fixed oscillators. A complete comparison between the fixed and stabilized systems will thus not be possible but, nevertheless, the modification is expected to lead to the improved performance of the stabilized equipment.

This paper has been read in manuscript by Dr. W. Halliday (Chief Physicist, Acoustics Division) and Mr. C. S. Sparling, of Kelvin and Hughes Ltd.; to them I am grateful for advice and valuable suggestions. At the same time I should also like to express my appreciation of the help so freely given to me by my colleague, Dr. J. S. Swallow.

REFERENCE

HERDMAN, H.F.P. (1948), Soundings taken during the Discovery Investigations. *Discovery Report*, **25**, 53.
