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Searching the sea with sound

... an international symposium on sonar systems held ... Birmingham last week the future of non-military ... (asdic) was discussed. Improvements in technique ...d make possible the observation of individual ... fish, while the study of the sea-bed ... be assisted by better directional devices

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...AR (Sound Navigation and Rang-...) has been coming into the open re-... after many decades of hiding behind ... of security restrictions. Last year ...portant Nato "advanced study insti-..." ... underwater acoustics was held in ... and although only a few selected ... were invited to take part, the insti-... work will shortly become generally ... through the publication of its ...ngs (Plenum Press, New York). ... another important step has been ... the holding of a fully-open Sym-... on Sonar Systems—thought to be ... ever of this scale and scope—last ... at the University of Birmingham ... the joint sponsorship of the British ...on of Radio Engineers (Electro-...cs and Radar Groups), the ... of Physics and Physical Society ...s Group), and the Electrical En-... Department of the University of ...ham, which has a large sonar re-... programme. Most of the papers ... concerned with fundamental prob-... of sonar, which apply equally to its ... military operations (such as the de-... of submarines) and in non-military ... seven dealt specifically with im-... non-military uses, such as in ... research and operations, hydro-... surveying, and geophysical and ...phic research. It has, indeed, be-... clear in recent years that non-... applications of sonar, which also ... navigation, are growing rapidly in ..., and it is largely their needs ... for the open exchange and pub-... of scientific and technical in-...

Sonar—or "asdic" as it has traditionally been called in Britain—is concerned with gathering information about the presence, position and nature of objects by means of sound waves. It most frequently takes the form of an echo-location system used in water. The typical simple sonar system, like a radar system, uses the transmission and reflection of a pulse of energy as its basis: it comprises the main components shown in Figure 1. Individual systems show many variations on this theme.

The transducers for converting the electrical signal into an acoustic one, and vice versa, may be regarded as a sort of loudspeaker and microphone respectively, although they generally rely on either the magnetostrictive or piezo-electric effects for their operation.

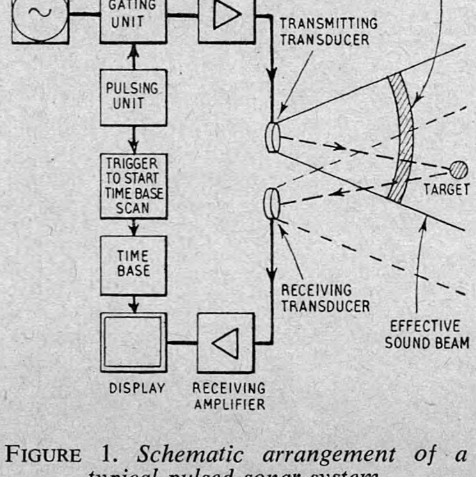

FIGURE 1. *Schematic arrangement of a typical pulsed sonar system.*

Although cathode-ray displays are being increasingly used, the commonest type of display in simple systems is still the chemical recorder, in which a moving roll of impregnated paper is scanned by an electric stylus. Typical recorder traces are shown in Figure 2. If there is a definite reflecting object—or "target"—in the sound beam, then the echo-pulses it produces give consistent marks on the trace at each traverse and form a line down the paper. If the range of the target from the transducers does not vary, then this line is parallel to the direction of motion of the paper. If the range changes because of the motion of the target or of the ship on which the equipment is fitted, then the line is sloped relative to the paper motion.

General problems.—The papers at the symposium were of two main types: one concerned primarily with the equipment and the other with the medium (the sea) and the target. Among matters concerning equipment were the general problems of how arrays of transducers could be used to produce more narrowly directional sonar beams, how beams could be made narrower without increasing the size of the array, the properties of three-dimensional arrays, the general problems of signal processing and of display (that is to say, the "information theory" of sonar), and practical arrangements to meet specific needs.

Concerning the medium, propagation is the most perplexing subject; for however good the equipment may be, its performance as a sonar will always be limited by the perversities of acoustic propagation in the sea. Refraction due to thermal gradients, varying salinity, etc., absorption of energy by conversion into heat, scattering due to inhomogeneities and to rough boundaries (sea-surface and sea-bottom—and one paper dealt with the effects of rough ice), all make sonar performance hard to predict and unreliable. Other topics concerning the medium included the difficulties of obtaining constant echoes from complex targets when the transducers are on a moving ship, and the directional properties of the ambient noise background in the sea.

Non-military applications.—The most interesting part of the symposium for the non-specialist was probably the final informal discussion on the future of non-military sonar. An account of the main points which emerged is given below. This necessarily to a large extent corresponds with the research programme in sonar of the Electrical Engineering Department at the University of Birmingham, since this group is concerned entirely with non-military applications, and is probably the largest such group in Europe. But other British groups, such as those at the stitute of Oceanography and ries Laboratories at Lowestoft een. contribute to the pro- d help in its formulation. In on many other interesting and oposals were made, which, e still very speculative. One of l to the use of air-sonar for the overcraft. There was also some medical applications of the f sonar.

research and fishing operations. s work it is necessary (among) to know the whereabouts and of fish, and their numbers, size, , and in these respects sonar spect of being able to provide ation. Hitherto single-beam een used, and when used verti- "echo-sounder" gives valuable about the fish beneath the tunately the ship usually has an n motion, which causes the rom the sea-bottom to form a s the ship progresses along its an be seen in Figure 2), and it difficult to detect fish which ear the bottom. Means have oped, however, for referring ero to the sea-bottom, so that appear at their proper height pproximately flat bottom trace. displays of such bottom- es are very valuable, too, and ssible to count the fish passing e beam within a given height ottom when the beam is fairly

e beam is used nearly horizon- a large volume of sea can be he single-beam sonar falls very of ideal performance. As it is o wait in every position of the ne or two transmitted pulses to n any fish at maximum range ing the beam to a new position, hat with a velocity of sound in nly about 1 mile/sec it takes a to search a large area with a narrow beam. Thus much in- s lost. A promising development d is the "within-pulse electronic ning" sonar, which enables a eiving beam to be swung over tor ("insonified" or illuminated nsmitted pulse) so fast that the rtually looks in all directions in at once. A suitable cathode-ray nables information from the or to be presented on a single smission—see Figure 3, which oal of fish in the North Sea as experimental sonar using rela- rse resolution. Such equipment y been used in fish research, and potentialities.

resolution version of this system, angular resolution over a 30° a few hundred feet radius, with

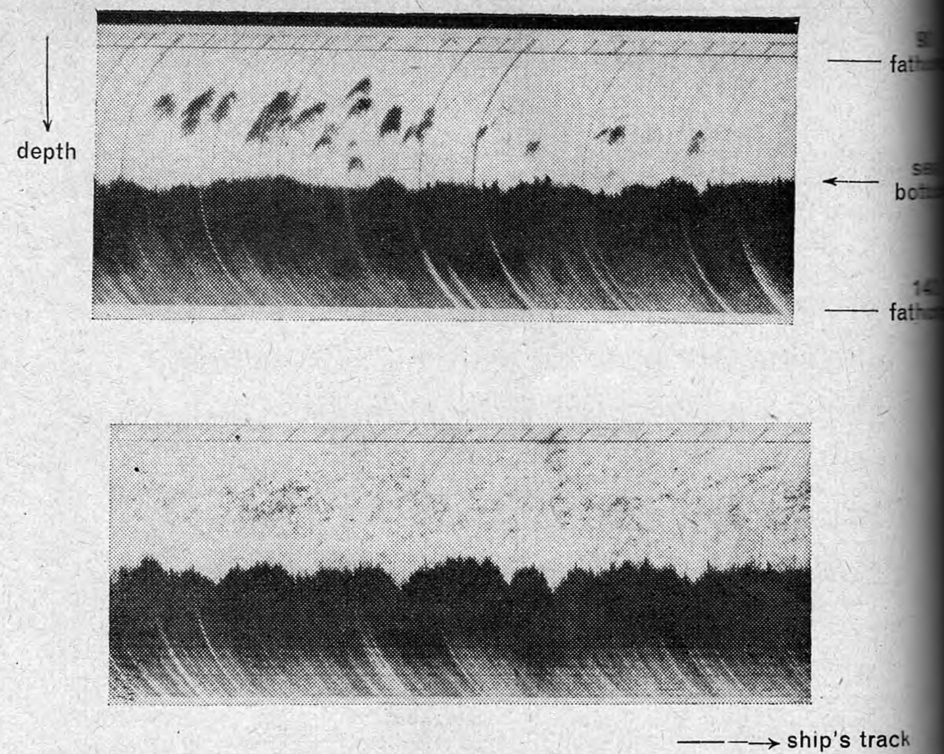

FIGURE 2. *Typical echo-sounder traces on chemical recorder paper, showing bottom profiles, with small shoals of cod in mid-water. In the upper picture are agglomerated; in the lower they have become diffused. (Courtesy,* Journal British Institution of Radio Engineers.)

6-inch resolution in range, was demonstrated at the symposium. It is hoped that such an equipment will enable the movements of *individual small fish* to be studied. The maximum range at present is limited by the use of a relatively high frequency (500 kc/s) which enables the transducers to be of manageably small size, but suffers a high absorption loss in the water. It seems desirable that the principle be

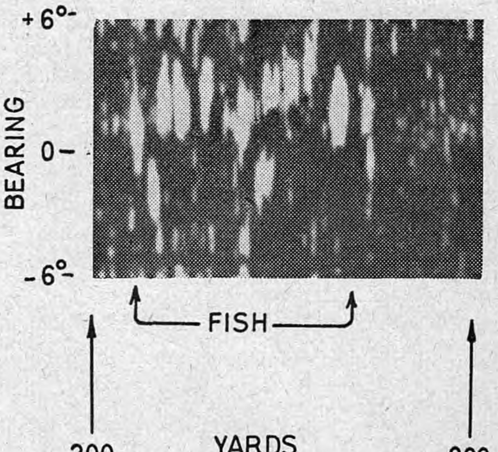

FIGURE 3. *Typical display of fish shoals obtained with an electronic sector-scanning sonar with 1.5° resolution. (Courtesy,* Journal of British Institution of Radio Engineers.)

extended to lower frequency system ranges of the order of a mile or with higher angular resolution whether such high resolution can b tained at such ranges in shallow, in geneous and turbulent water has yet investigated.

Present electronic scanning system a fan beam which has a relatively vertical angle (say 12°) and scans horizontally. But clearly fisheries re calls for the scanning of pencil bea two planes. Suitable and economical arrangements were discussed in a posium paper, but whether it is possi scan fast enough to cover a large sector without loss of information h to be determined.

Another matter in which sonar m able to help is the identification of Hitherto fisheries experts have had to some sort of identification from the of echoes from shoals. Apart fro possibilities which may be develop actual delineation of the larger fish, are possibilities also in the use of a wide frequency band for the sonar so that the frequency-response of the as a sonar target could be displayed. tional sonar systems with constant tivity over a 10-to-1 frequency rang under development for this purpo has not yet been determined whethe would identify the larger fish, but

4. *Sector-sc*

es seem pron s those compri er. This is a organisms, oc of great pote whose exist from echo-so constitution an being discover to have reson to the swim-b equency range ment of equi cal and exper on the echo and shape of fi

point was r discussions du sonar which rmen in comm from research) ent emphasiz frequency-mo not visual—p n might be s *graphic and* —Sonars, in rs, have been ning depth s charts, and m making the and in dete of the sea s accurately nder reasona th a flat se to a few fath s of several t ig limitation beamwidth u a sloping or i

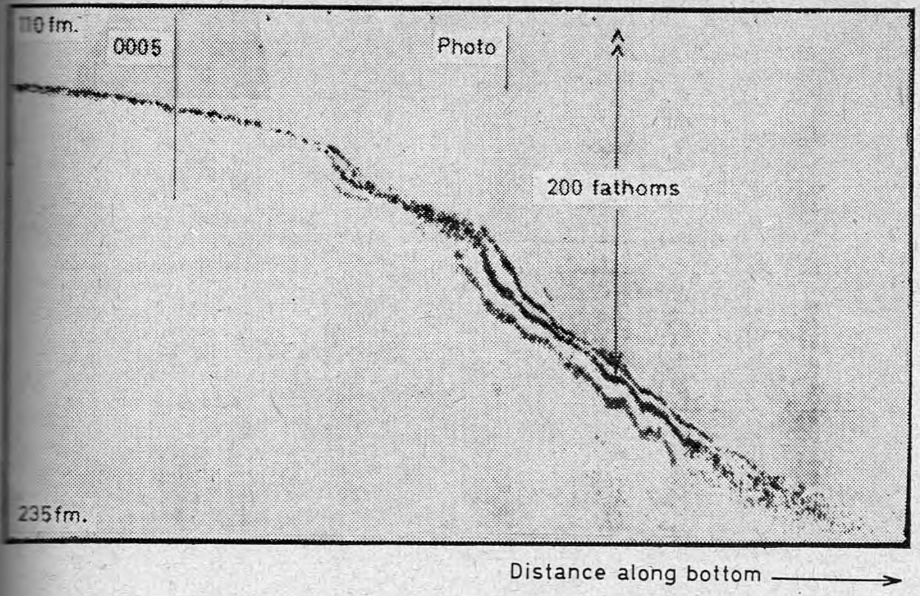

FIGURE 4. *Sector-scanned record of 45° slope on sea bottom. (Courtesy, Institute of Navigation.)*

...y does seem promising for small fish, ... as those comprising the deep scat-...g layer. This is a relatively dense mass ...all organisms, occurring widely in the ...s, of great potential importance as ...stuff, whose existence has long been ...n from echo-sounding records, but ...e constitution and distribution is only ...y being discovered. These small fish ...r to have resonant frequencies (due ...ly to the swim-bladder) in the usual ... frequency range. In addition to the ...opment of equipment, much more ...tical and experimental research is ...d on the echo response of various ... and shape of fish (as well as other ...s).

...e point was repeatedly made in ...l discussions during the symposium ...y sonar which was intended for use ...ermen in commercial operations (as ...t from research) must be cheap. This ...ement emphasized a proposal that ...e frequency-modulation sonar with ...—not visual—presentation of in-...tion might be successful.

...rographic and oceanographic sur-...—Sonars, in the form of echo-...rs, have been used for a long time ...aining depth soundings for naviga-... charts, and much work has been ... in making the equipment basically ...te and in determining the velocity ...re of the sea so that time of travel ...be accurately converted to depth. ... under reasonably good conditions ...with a flat sea-bottom, soundings ...te to a few fathoms are now possible ...ths of several thousands of fathoms. ... big limitation of existing systems is ...de beamwidth used—commonly over ...n a sloping or irregular bottom there is thus always an uncertainty as to the point from which the first echo returns are received, and thus accurate surveying is impossible. Very narrow single beams have disadvantages, too, and it seems that a great advance may be possible by using electronic sector-scanning sonar in this depth-sounding role. A profile of the bottom can be obtained in this way not only with many fewer traverses by the ship, and with much greater accuracy, but also in worse weather conditions. Figure 4 shows a steep slope on the edges of the continental shelf recorded with a single pulse by a very crude experimental system.

Even simpler devices than a scanning sonar can be used to improve surveying. Figure 5 shows a record obtained using a multi-beam non-scanning system. In this case three narrow beams of about 1.7° width (at the half-power points), with 6° spacing, were formed by a two-transducer system. On a slope, different ranges are measured by the three beams, so that three separated traces are obtained; the spacing measures the slope. In the case illustrated, the beams were arranged in the fore-and-aft plane, so that the slope indicated agrees with that determined from the profile of the trace as the ship moves along.

It has already been shown that sonar can be used to give valuable information on the geological nature of the sea-bottom due to the different scattering properties of different kinds of rock and sediment (see A. H. Stride's article in the *New Scientist* of 11 May, 1961). It is probable this kind of use can be refined; possibly wide signal-frequency bands will improve the quality of the information obtained. The use of high-power sound sources (such as explosions, sparks, mechanical impact) is already permitting penetration of the upper layers of the sea-bottom as in geophysical (seismic) methods. Evidently considerable development in this direction may be expected.

It is possible that methods will be found of using sonar systems to measure ocean currents at various depths by exploiting the Doppler shift of frequency in the sound back-scattered by the inhomogeneities in the water.

Special problems arise in the surveying of inland waters and particularly waterways, where wide but shallow channels are concerned. Attempts to solve these problems (as represented in a symposium paper, for example) have so far relied on a multiple assembly of individual sonar systems; but new and more economical methods are perhaps possible.

There are many other possibilities (in civil engineering, for example) which space does not permit to be discussed here. One can sum up by saying that sonar has a good future in the non-military field, but that intensified research and development will be necessary if its full potentiality is to be realized.

Of the 29 papers presented at the meeting, 26 were preprinted in two bound volumes: some extra copies are available for purchase from the Brit.I.R.E., 9 Bedford Square, W.C.1. Price 52s. 6d.

FIGURE 5. *Record obtained with 3-beam echo-sounder. (Courtesy, Institute of Navigation.)*