Sector-Scanning Sonar for Fisheries Purposes

by

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Abstract

Research at the Electrical Engineering Department of the University of Birmingham has led to the development of electronic sector-scanning sonar systems which can be valuable in fisheries work. Early experiments at sea demonstrated that such a system was very effective in delineating schools of fish either ahead of the ship or below it. The latest development in the equipment itself, its performance (particularly with respect to angular resolution), and its manner of use have led to the possibility of the accurate detection and location of fish very near to the sea bottom. Moreover, the receiving part of the equipment has been developed in a universal form which can be used with any acoustic frequency within a wide range, and thus without difficulty and with great saving of cost can provide a general-purpose sonar suitable for high resolution at short ranges or lower resolution at longer ranges, using different transducers but the same electronic system. It seems clear that the equipment is now ready for commercial exploitation in fisheries.

Balayage de secteur en sonar pour la pêche

Résumé

La recherche dans le Département Technique Electrique de l'Université de Birmingham a mené au développement de systèmes sonar de balayage électronique de secteur qui peuvent être valables dans la technique des pêches. Des expériences conduites en mer ont démontré que ces systèmes sont très efficaces pour tracer les bancs de poissons repérés en avant ou sous le bateau. Les derniers développements dans l'équipement luimême, son fonctionnement (respectant particulièrement la résolution angulaire) et les modes d'emploi ont mené à la possibilité de détecter et de localiser précisément les poissons se trouvant près du fond. Le récepteur de l'équipement a été développé sous une forme universelle de telle sorte qu'il peut être utilisé dans une large gamme de fréquences acoustiques. De cette façon on peut facilement et à peu de frais construire un sonar à but général qui convient pour une haute résolution à courte portée ou une basse résolution à longue portée, utilisant des émetteurs différents dans le même système électronique. Il semble que l'équipement est maintenant prêt pour l'exploitation commerciale dans les pêches.

El sonar de exploracion por sectores en la pesca

Extracto

Las investigaciones realizadas en la Facultad de Ingeniería Eléctrica de la Universidad de Birmingham han culminado en la fabricación de aparatos de sonar electrónicos de explotación por sectores que pueden ser muy valiosos en la pesca. Los primeros experimentos realizados en la mar demostraron que tal sistema es muy eficaz en la localización de cardúmenes delante o debajo del barco. Los más recientes adelantos en el material, su rendimiento (particularmente con respecto a la resolución angular) y la manera de usarlo han creado la posibilidad de encontrar y localizar con exactitud cardúmenes muy cerca del fondo. Además, la parte receptora de los aparatos se ha perfeccionado de forma universal que puede emplearse con cualquier frecuencia acústica en una gama muy amplia con ello, sin dificultad y con gran economía de coste, constituye un sonar de múltiples usos a propósito para lograr gran resolución a poca distancia o resolución más baja a distancias mayores empleando diferentes transductores pero el mismo sistema electrónico. El material está ya listo para su explotación en la pesca industrial.

EXISTING sonar, asdic, or echo-sounding equipments which are commercially available always use a single fixed beam, usually several (or many) degrees in width. In the case of equipments designed to use the beam in an approximately horizontal position, provision is made for swinging the beam by rotating the transducer bodily. If it is desired to scan a sector, then it is necessary to allow time for a pulse to travel out to the maximum range and for echoes to return to the transducer before the beam is rotated to its next position. Since the speed of sound in water is very low, about a mile a second, it clearly takes a great deal of time to search a large sector effectively. A compromise has to be made between beamwidth and speed of search. Generally the beamwidth is of the order of 5°, which not only gives a rather slow rate of search but is quite unsuitable for detecting fish near the sea bottom because of the high background of reverberation which such a large beamwidth produces.

Electronic sector-scanning sonar (Figs. 1, 2, 3, 4) overcomes these difficulties. The way in which it works is shown in Fig. 1. A relatively wide sector, say about 30°, is illuminated by a pulse transmitted from a transducer having a wide beam. The receiving beam is made very narrow, say 1°, and by electronic means is swept rapidly from one side to the other of the sector, the process being continuous and repetitive; the time required for one complete sweep is equal to the duration of the transmitted pulse. This means that all directions within the sector are sampled before the pulse has moved its own length through the water. In other words, the whole width of the sector is virtually simultaneously examined; and by the time the pulse has reached its maximum range, information has been received from all points in the sector. It is thus possible to have the receiving beam as narrow as may be desired without prejudice to the rate of search. The method of displaying the information is also indicated in Fig. 1. The most effective display seems to be the B-scan on a cathode-ray oscilloscope; this is a display in which range and bearing are used as rectangular co-ordinates, the range time base being synchronised with the movement of the pulse as it passes through the water, and the bearing time base being synchronised with the electronic sweep of the receiving beam. Any echoes received from targets within the sector of search are thus displayed at the correct range and bearing. There is of course a distortion in this kind of display, and from some points of view a triangular display, which would more nearly resemble a P.P.I. sector, should be preferable. Experience, however, shows that this is not satisfactory owing to the crowding of echoes at short ranges.

The width of the transmitted and receiving beam in the plane perpendicular to that of the sector of search

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be as large or small as is desired or necessitated by cular applications. In typical experimental equip- s this beamwidth has been 12°, but it is now thought for many applications a width of perhaps 5° would tter.

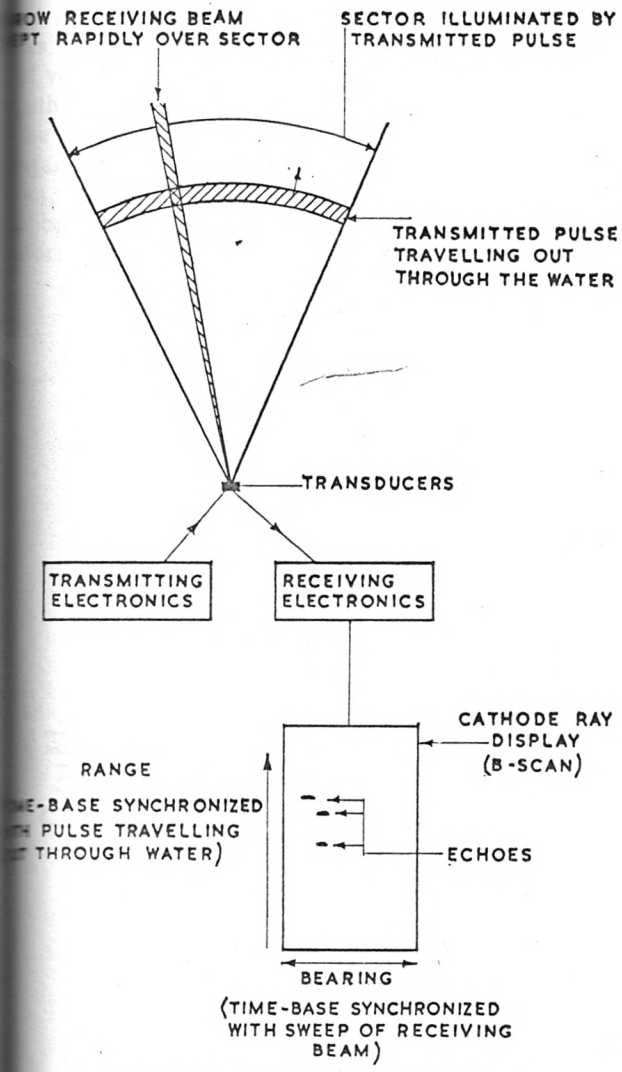


Fig. 1. Schematic diagram of sector-scanning sonar.

order to scan a sector with a receiving beam which e nth the width of the sector, it is necessary to have eceiving transducer divided into n sections and to n electronic channels connecting these sections to ater parts of the receiving electronic system. The se of the system is therefore to some extent ased by having a larger number of beamwidths with- e sector, in other words by increasing the resolution e system. The order of resolution which it is thought d be readily feasible and commercially worthwhile rhaps 1° angular resolution[1] and one m range tion in a system operating around 50 to 100 kc/s giving ranges between 500 and 1,000 m on fish ls. Very much higher resolution is worthwhile in cations where shorter ranges are acceptable, and a t equipment has given a resolution of half a degree in angle and about 10 cm in range up to a maximum range of about 100 m. The former system would be suitable for detecting large fish such as cod, or small schools of fish, at reasonable distances. The latter system is intended for the observation of fish movements and perhaps the identification of individual fish in more limited situations, notably in enclosed waters, and in positions of special significance such as the intake to the turbines of hydro-electric power stations and to the cooling water system of thermal power stations, the observations of fish entering nets, and so on.

Observation of fish in midwater

One of the difficulties in sonar work when using beams which are very nearly horizontal is that the scattering of sound from the sea bottom (also from the sea surface) produces a background against which it may be difficult to detect fish. If the water is fairly deep, it is possible to have the beam clear of both the surface and the bottom up to quite reasonable ranges, and in these circumstances midwater fish may be detected without difficulty. The parameters of the system are then not very critical, and success has been obtained with ordinary single-beam sonars having beamwidths of as much as 5°. Of course the problem of search still remains, but perhaps with 5° beams the time required to search a sector is not prohibitive. Nevertheless a simple electronic-scanning system can give a very considerable advantage, and with a resolution of 5°, not many channels are needed to cover a big sector. Thus the equipment need not be very expensive. But obviously if a narrower beam is used, say 1° in plan (although it may be say 10° vertically), much better resolution is obtained and the details of the fish school are more clearly determined.

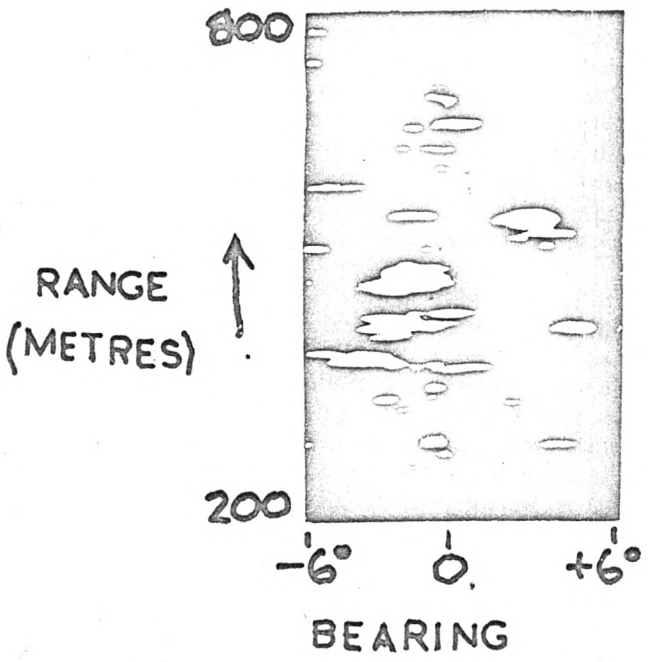
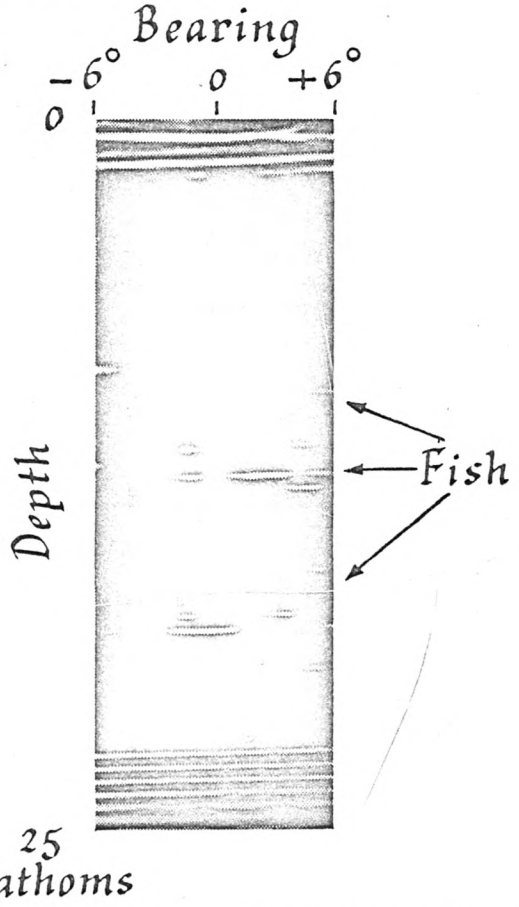


Fig. 2. Typical 8-channel sector-scanning display showing small fish schools. (Horizontal beam.)

Echo sounders, i.e. sonars with their beam axes vertical, e frequently used for detecting midwater fish. They e very successful in this role in spite of having very ide beams, often over 30°, because there is no possibility bottom or surface reverberation forming a background the same range as the fish. The only background is lume reverberation, i.e. scattering from particles and bbles, etc. in the water, and this reverberation is gener- y of very low level. But even with such a system as is, although detection is very good, resolution is poor d the details of schools cannot be determined. So re again the use of electronic sector scanning could be asset, and only a relatively small number of channels ould be required to give a very big improvement in e information obtained.



3. Typical 8-channel display with sector axis vertically below ship.

Some examples of results obtained in a relatively mple eight-channel electronic sector scanning sonar e shown in Figs. 2 and 3. In this system the acoustic equency was 37 kc/s, the horizontal beamwidth was 5°, the pulse duration was 1·0 millisec, and the vertical amwidth was 12°. Since there were eight channels, the dth of the scanned sector was about 12°. Fig. 2 shows me results obtained with an almost horizontal beam, anning in the horizontal direction. In interpreting s display it must of course be realised that the range and aring scales are such that a true plan view is not presen- d. But it can clearly be seen how the small schools of fish are distributed and it is not difficult to interpret these in strict geometric terms if required. Since all this information is obtained on one single transmitted pulse, it is clear that there is no confusion due to movement of the fish or of the boat while the search is being made.

Fig. 3 shows a result obtained with the axis of the scanned sector vertically below the ship. The parameters of the system were the same as in Fig. 2 but, owing to the short range at which the fish are now being detected (the depth of the water was only about 40 m), it is likely that at least some of the echoes shown are due to individual fish (probably herring).

It will be seen that, even with such a comparatively crude system, the improvement in the information obtained over that obtained with an ordinary sonar is very marked.

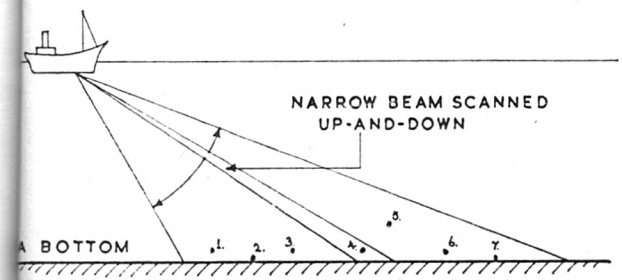
Detection of fish very close to the sea bottom

An important problem in fisheries is the detection of fish near the sea bottom because this is where a very great deal of trawling has to be done. If the beam is directed at a shallow angle to the bottom, it is clear that fish near the bottom have to be detected against a background of the reverberation, or backscattering from the bottom itself. Because of this factor most commercial single-beam sonars have not been very successful in this role. With a beamwidth as wide as 5° horizontally, too much of the bottom is taken in by the pulse and the reverberation from this is ample to drown the echoes from fish.

The use of an electronic sector-scanning sonar using horizontal scanning, as in the example shown in Fig. 2, can effect a very considerable improvement because it permits the use of very much narrower beams, thus greatly improving the ratio of fish echo to reverberation background. The typical result shown in Fig. 2, indeed, was taken under conditions where bottom reverberation was of importance because the depth of water was only about 40 m and, with the vertical beamwidth of 12°, bottom reverberation was, in fact, being received over most of the range. It will nevertheless be seen that the fish schools show up quite clearly in spite of this. There is no doubt, however, that bottom reverberation must be always a limiting factor in the detection of fish when the sonar system is used in this way.

Recently a completely novel way of utilising a sector-scanning sonar for the detection of fish very near the bottom has been proposed by Dr. F. R. Harden Jones of the Lowestoft Fisheries Laboratory. The principle of this new system is shown diagrammatically in Fig. 4. Instead of the beam scanning horizontally, it now scans vertically as indicated by the arrows in the diagram. The beamwidth in the direction at right angles to the plane of the diagram may be quite considerable, and something between 5° and 12° is thought to be most suitable. As the receiving beam (narrow in the vertical plane) swings up and down as indicated, it returns echoes from the sea bottom varying from comparatively short range in the lowest position to a comparatively long range in the highest position; the sea bottom returns,

efore, appear as a curved line on the B-scan display hown in Fig. 5. Any fish near the bottom, such as e indicated by numbered dots in Fig. 4, return echoes ch are received before the bottom echo for the icular beam position along which they are received. fish echoes therefore appear clear of the sea bottom , as shown by the numbered echoes in Fig. 5. , therefore, is a very effective system of obtaining es from fish very near the bottom without inter- nce from the bottom returns themselves. In fact the om returns are made use of to provide a reference on the display. In a way this new system is a com- mise between the ordinary conception of scanning ad of the ship and the conception of the echo sounder.



4. Application of sector-scanning sonar for the detection of fish near the sea bottom.

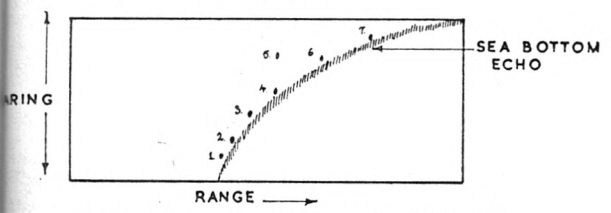


Fig. 5. Display obtained by method of Fig. 4.

But scanning in this particular way clearly gives some very considerable advantages.

Although no experiments have yet been carried out at sea using this method of search, some very extensive trials of it have been made in a large seawater tank at Cairn Ryan. The experimental electronic sector-scanning sonar used for these trials was a high-resolution equipment having 30 channels, so that 30 beamwidths are scanned within the sector. Moreover, the system was provided with a special kind of signal processing which enables double the angular resolution of a normal acoustic system to be obtained with the same size of transducer. In this experimental equipment the acoustic frequency was 500 kc/s, and the pulse duration was 0·1 millisec, giving a resolution of about 10 cm in range. The sector width was 30°, and the resolution was about 0·5°. The sea bottom was simulated by the concrete wall of the tank or by a corrugated sheet, and fish targets close to the bottom were simulated by artificial small targets or by actual fish suspended in position near the wall. Some typical displays obtained in this trial are shown in Fig. 6. It will be seen that they reproduce the theoretically expected picture exactly, and promise great success for Dr. Jones's system. It is intended to carry out operational sea trials of this method next winter, using an acoustic frequency of 100 kc/s, with an angular resolution of 1°. It seems probable that success will be obtained, and that this will prove a most important development in the use of sonar in fisheries.

[1] By "angular resolution" is meant the smallest angular step over which a change in target strength can be detected. The problem of separate detection of two fish with a clear patch between them, or of one fish clear of the bottom, involves *two* such steps. Thus

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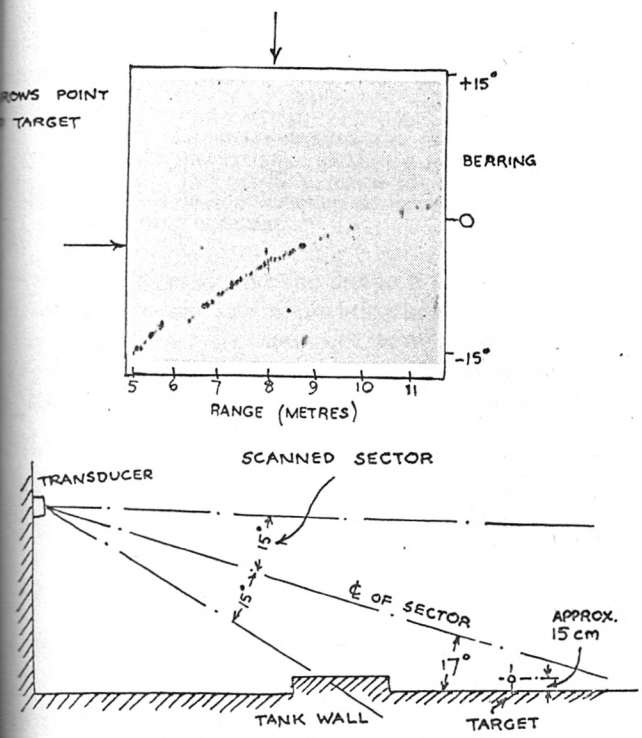

Fig. 6. (a) Typical results with 30-channel system.

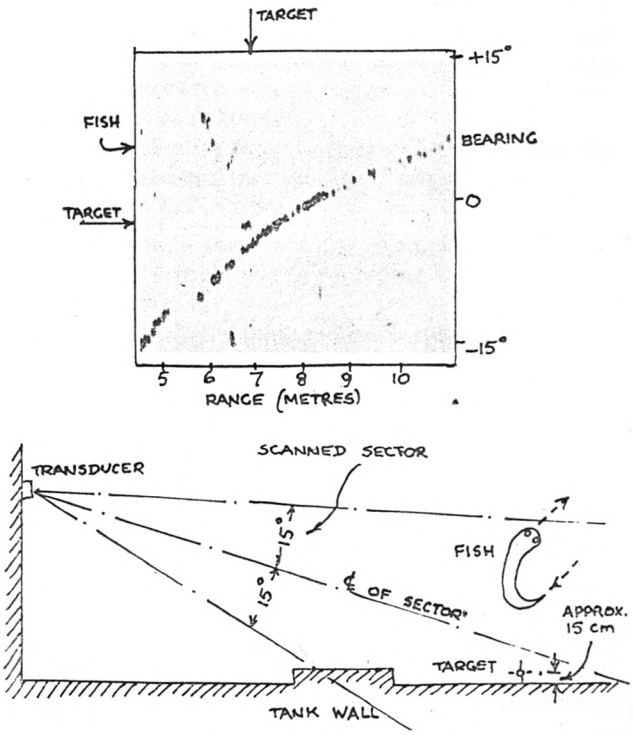

Fig. 6. (b) Typical results with 30-channel system.