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A SECTOR SCANNING SONAR SYSTEM: TEN YEARS OF USE

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Introduction

In 1969 the Admiralty Research Laboratory 300 kHz sector scanning sonar, together with a specially developed transducer stabilizer, was installed in the Ministry of Agriculture, Fisheries and Food, Research Vessel CLIONE. The installation and trials have been described (1) as have further developments of the electronic scanning system (2). This paper outlines problems and the changes which have taken place over the past ten years in the system as a whole. It says much for the original ARL development (3) that little of the receiving system concept has changed, but improvements in technology and electronic techniques have led to a more compact and easily maintained sonar.

Ship fitting

One of the problems which arose initially, and is always a matter of importance where physically large transducer apertures are necessary, is the mounting arrangement on board ship. Proposals were considered for both the conventional inboard fitting and also an open trunk, extending from keel level to above deck and the latter allowing access to the complex stable platform, in addition to the transducer, without the need to drydock the ship. Although an unconventional approach at the time, it would not have been possible to continue the use of this sector scanning sonar without such ready access to the underwater system (Figure 1). One disadvantage was the restriction of trunk diameter (0.76 m) to less than the transducer length (0.9 m); because of this diver assistance has occasionally been needed to turn the transducer into a vertical position for raising through the trunk to deck level.

Transducer and dome

The original installation included a dome which had to be keel-hauled into position before operations could commence, and which was removed in the same manner. Its purpose was to reduce flow noise at the transducer face, but the stout iron cage used to support the canvas or terylene cover also provided some protection from both water pressure and submerged debris. The dome caused limitations to the operation of the ship through a speed restriction of 7 knots which was imposed in order to avoid damage to the cover. Furthermore it had to be fitted to the ship in a deep-water harbour. A further problem was the effect on the beam patterns for transmission and reception: in addition to the cover loss of 5 dB each way, the cage introduced severe fluctuations to the signals. Early trials established that no measurable flow noise occurred up to the speed limit, but, because the transducer was unique and it had a soft rubber diaphragm, physical protection was necessary. By 1975 the soft rubber had been replaced by 7 mm thick moulded polyurethene with no greater acoustic loss (less than 1 dB). It was much stiffer than the rubber and was unaffected by leakage of hydraulic oil which had attacked the other material. The recent introduction of a polycarbonate diaphragm overcomes the need for protection of the transducer array, for it is very tough, has a smooth surface and very low acoustic loss (4).

Problems with the pressure release material used in the construction of this type of array were reported (5) and eventually a fully encapsulated design by Loughborough University was put into service, but still fitted inside the aluminium bronze housing filled with castor oil. This is still in use. Typical performance for these arrays is given in (5). Many series of acoustic measurements have been made over the years to obtain source level and beam patterns plus receiving sensitivity. These measurements have either been made at fixed range with the hydrophone or projector rigidly attached below the ship, or at ranges out to 300 m with instrumentation in a small boat or anchored above the seabed. Full power output from the 20 kW solid state transmitter is rarely necessary, so each of the ten 2 kW modules can be individually switched. Thus the most suitable power level can be selected for optimal working conditions by minimizing reverberation.

Stable platform

The stable platform (Figure 2), designed and built to MAFF specification by S. G. Brown Ltd, is hydraulically operated by the actuation of gimbals by rams controlled by electro-hydraulic servo valves. Control signals for these valves originate from a two-axis vertical gyroscope fitted at the meta-centre of the ship. Early in 1979 the stable platform was given its first thorough overhaul, every part being stripped down for examination. Due to careful choice of materials, corrosion has been no problem. However, in some areas specialized engineering techniques were needed to reclaim and replace components. These included the lower leg, oil seal surfaces, which were re-sleeved, and bearing surfaces in the azimuth gearbox. Attempts to strip electroless nickel from the aluminium bronze hydraulic slipring assembly were unsuccessful so a new unit was made. A new set of rams were manufactured because those in service had worn beyond acceptable tolerances. Some additional access holes were cut in the housing to relieve servicing problems. A summary of the types of fault that have occurred, details of hours run and the life expectancy for some of the hydraulic and mechanical components of the stabilizer are given in Tables 1 and 2. When first brought into service a high level of wideband noise was generated by the control valves, rams and hydraulic motor. Measures adopted to overcome this consisted of acoustically isolating the hydraulic valves from the body of the stabilizer by spacer; and from the sea, by cladding them with lead sheet and neoprene with closed air cells to prevent radiation. Metal, butt-jointed piston rings in the rams were replaced by 'X' section sealing rings. These measures have remained largely unchanged, the least satisfactory part being the disc of closed air cell neoprene placed across the lower end of the stabilizer's cylindrical housing. Because the transducer support leg projects through this disc, the latter is subject to wear as the leg moves in response to pitch and roll movements of the ship and azimuthal steering of the transducer; as a result it has to be replaced at regular intervals. Whilst the disc is in good condition, no noise from the hydraulic system is detectable at the transducer face. The receiving section of the sonar has a detection threshold close to the thermal noise level in the sea.

With a multi-element array stabilized in this way, signal processing must take place within the transducer housing, or a bulky cable results. Ten years ago the technology was not available for internal processing so a 76-way low-noise co-axial cable 40 mm OD was employed and a section of this is still in use. Each receiving transducer element has a radiation resistance of about 1200 ohms, but there are practical difficulties in fitting matching components and so the 50 ohm co-axial cable is connected directly to the elements causing a mismatch loss. A separate co-axial connected the transmitter to the array; at the shipboard end of the cable an inductive reactance is measured which must be tuned out for efficient operation. As only one component is needed, a cable matching arrangement could be fitted into the housing but this has not yet been attempted.

Displays

Improvements in sonar display technology are just beginning to become significant and it is very evident that we shall have need of the type of system directly or indirectly referred to in several of the papers in these proceedings (6,7,8). The present range/bearing displays rely on long persistence tubes which are only capable of giving about one-third of the line resolution required and, because of the relatively slow repetition rate of the sonar, the 'flash' must be filtered out to reduce operator fatigue, thus reducing the dynamic range displayed.

Although individual fish can be detected by the sonar, the identity of an acoustically passive fish target cannot be determined without physically capturing the individual, but for many fish behaviour studies such information is essential. In overcoming this problem, the use of sector scanning sonar has been greatly enhanced by the development of transponding acoustic tags, small enough to be fitted to fish species of commercial interest (9).

Acoustic transponding fish tags

These devices, fitted into polythene cases 50 mm long and 8 mm in diameter, comprise a transmitter producing a 3 ms pulse, with a source level of 164 dB/μPa/m; a receiver set to respond to signals above 105 dB/μPa, both being tuned to the centre frequency of the scanning sonar. The ring transducer was originally of 3 mm diameter and 3 mm high but it is now being replaced with one of the same diameter and only 1.5 mm high, thus improving the radiation pattern. Three mercury cells account for most of the weight, i.e. over 3 g of the total 7.5 g weight in air; the latter is reduced to 3.5 g in water. Operational life is largely dependent on the rate of interrogation; it is typically 32 h at 4 pulses/s and about 96 h at 1 pulse/s.

In order to keep size to a minimum with increased complexity hybrid microelectronic techniques are now employed for the development of tags telemetering physiological and positional information from free-swimming fish. This work has included the monitoring of real-time heart rate from a plaice in the sea, and more recently the introduction of a compass system, again fitted to a plaice. The same basic transponder circuit is used but arranged to give pulse interval modulation.

A mini-scanning sonar

During the course of work on transducer diaphragms an idea developed for the face mounting of ceramic elements to polycarbonate sheet. Experimental work was carried out and reported (4). This technique gives a simplicity of mechanical design which speeds assembly, consistently high performance, and a lightweight construction. The latter factor was of particular significance because the advantages of scanning sonar were denied in projects where small boats were essential, either in the sea or in fresh water. A transducer housing containing arrays for both horizontal and vertical scanning has been designed (4), the changeover being effected by electrical switching. The 3 x 3 stave transmitter array had a narrow beam in the original design but by increasing the angle between the stave axes to 20° this was increased to 23° at -3 dB points and 30° to the first zeros (Figure 3); preliminary trials with a 5 stave array show further improvements. Four sets of receiving arrays have shown a measured performance close to the theoretical, with a bearing resolution of 1.6° at -3 dB in one plane and 10° in the other. Preliminary trials at sea and in shallow fresh water, using a receiver developed for MAFF by Loughborough University, have shown good detection and delineation of seabed targets out to 300 m and excellent clarity in about 2 m depth of fresh water.

The immediate applications range from following the movements of crabs, eels and other fish, tagged with transponders, to the location and observation of the sub-surface buoys used in supporting arrays of current meters, but again these will have transponders fitted. The mini-scanner development programme at present underway will mean that all MAFF vessels can be fitted with some form of sector scanning sonar, most will have facilities for steering and tilting the arrays (Figure 4) but no stabilization. In addition there will be portable, battery powered versions of the mini-scanner for operation from rowing boats or dinghies. The advantages of picture-forming sonars of this type will be more in demand as their size and complexity decreases.

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References

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Table 1 Life table for hydraulic components based on experience

Item	Life expectancy (hours' running)
Hydraulic sliprings	800 or annual replacement
Azimuth drive motor	4000
Roll and pitch rams	3000
Servo valves	4000
Transducer leg (inner flexibles)	4000
" " (outer ")	8000

Table 2 A brief note of the faults record

HYDRAULIC STABLE PLATFORM

Total running hours to date, 8000

Under the control of the Research Vessel Support Team from 1973
5000 hours running time to 1979

<u>Some instances of faults</u>

Electronic problems

1973 Water seepage into damaged electronic control cable or its plug/socket interface on package. Partial or complete loss of control

Remedies: Rear of electrical connector filled with plasticized epoxy resin. More substantial 'O' ring fitted

1975 Water seepage into main electrical junction box and one of the five other boxes. Again through damaged outer sheath of a cable

Remedy: Cable entry into boxes sealed with silicone rubber

Mechanical/hydraulic

The initial faults on the stable platform concerned ram rod plating and acoustic noise. Solved by different plating techniques, cladding and isolation

Various component failures have occurred; the most unexpected being fatigue of tungham pipes, despite vibration tests and additional clamping during the acceptance phase

Divers needed on a few occasions to turn transducer into vertical position for raising into the trunk when either loss of control signals occurred or loss of hydraulic oil

<u>Brief history of electronic equipment</u>

Valve equipment returned to ARL at end of 1974
1st solid state receiver installed early 1975
Replacement valve transmitter in use
1st solid state transmitter installed early 1977

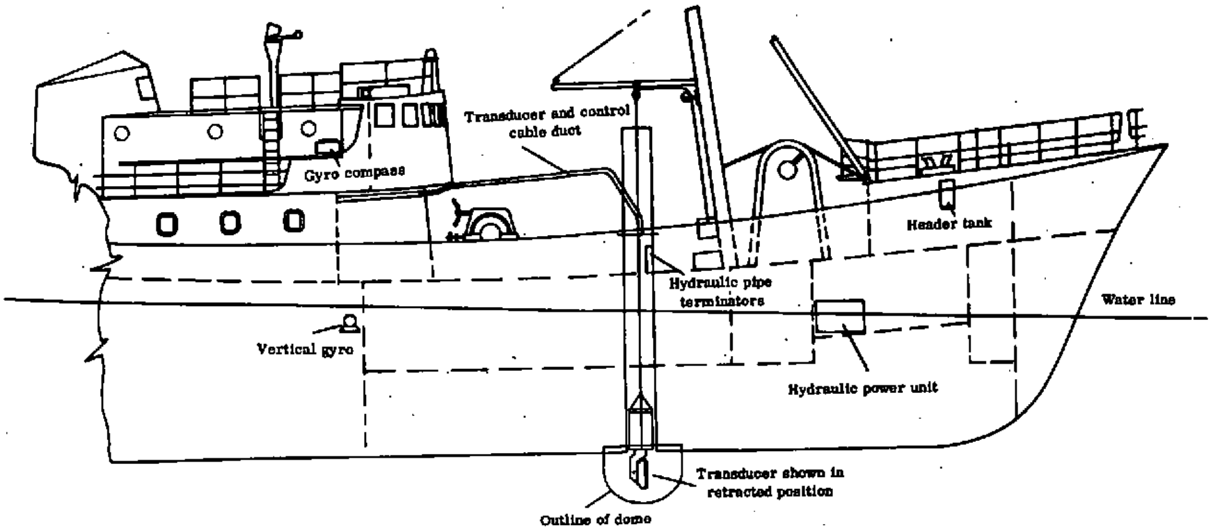

Figure 1 Shipboard installation.

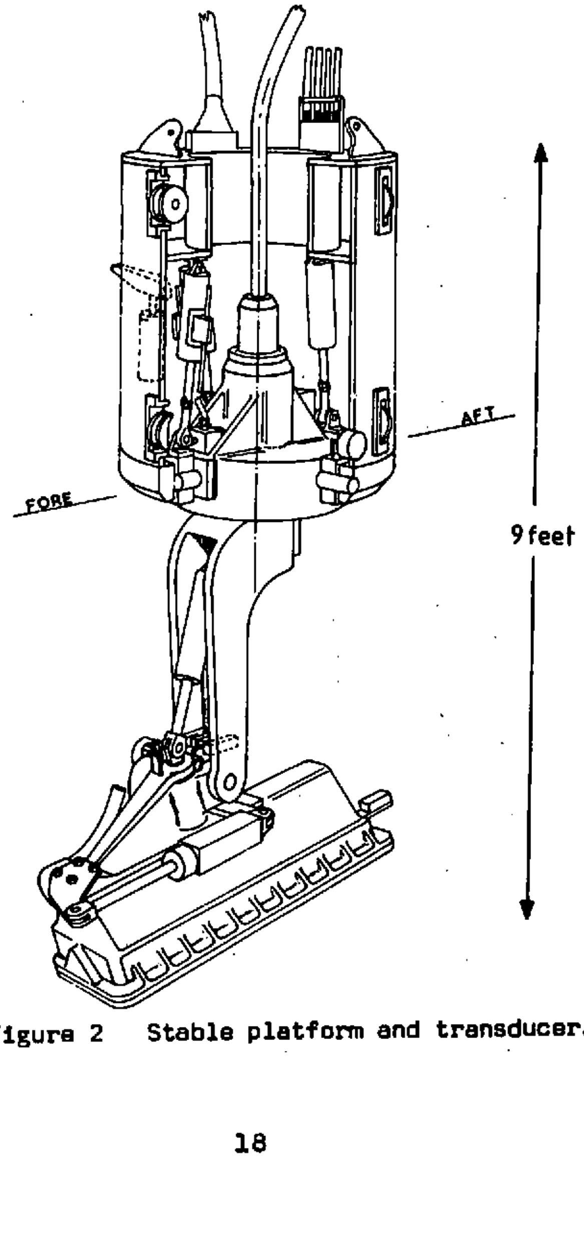

Figure 2 Stable platform and transducer.

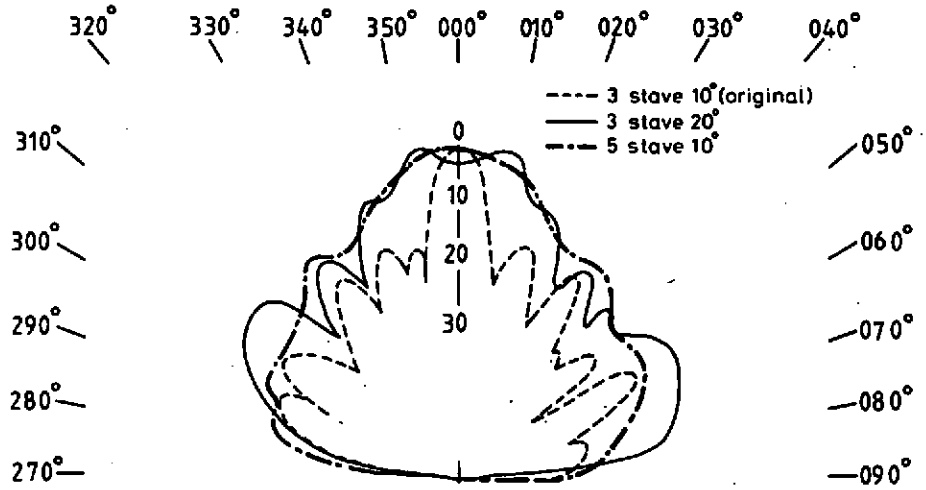

Figure 3 Transmitting transducer beam patterns.

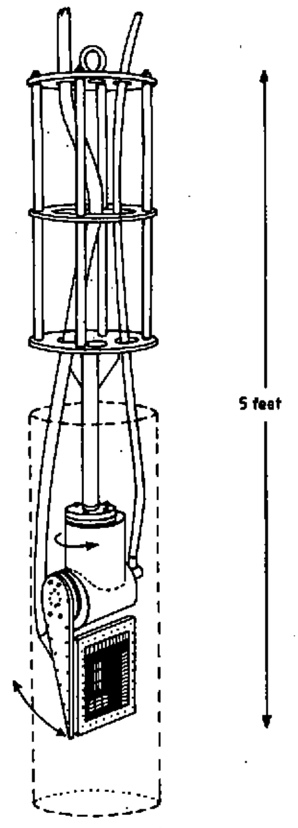

Figure 4 Mini-scanner head with pan and tilt.