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A transponding acoustic fish tag

by

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Introduction

Acoustic fish tags were first reported as being used successfully in 1957[1] and there are various other records of fish tracking[2, 3]. The tags used for the experiments described in these reports were transmitters, which emitted CW or pulse signals. Tracking was carried out by means of so-called searchlight sonars mounted in a suitable vessel for river or sea work. Whilst contact with the fish could be maintained to satisfactory ranges, dependent largely on the frequency of the carrier, it was not possible to obtain very accurate information on the position or movements of the fish.

When the transponding principle is used, the pulse from the ship's sonar transmitter is received by the tag, amplified and used to trigger the transmitter, thus sending a return pulse to the ship. This gives an accurate range measurement between the ship and the fish. The other measurements needed are bearing and depth, and these cannot be obtained with any degree of accuracy by the searchlight sonars because of the necessarily wide beams used in such equipments. A sonar equipment fitted to the fisheries research vessel CLIONE has, however, more adequate characteristics. This is an electronic sector scanning sonar known as the ARL scanner. It has a unique facility whereby either azimuth or elevation scanning may be selected at will, the changeover from one to the other being accomplished in seconds. Thus the position of a target in the water column may be determined, relative to the ship, within the accuracy of the receiving beam, which has an angular resolution of 0.33° in the scanning plane. The beam in this plane covers a sector of 30° (Figs. 1 and 2).

Fisheries Laboratory acoustic tag

Although single fish can be detected and followed by such equipment without the use of acoustic tags, individuals cannot be identified. A transponding acoustic tag has therefore been designed to assist in the study of fish behaviour, migration, reaction to fishing gear and movements relative to bottom features.

To obtain the high angular resolution of the ARL sonar with a transducer of practical dimensions, the operating frequency is high, i.e. 300 kHz. The use of such a frequency for fish tags creates a number of difficulties,

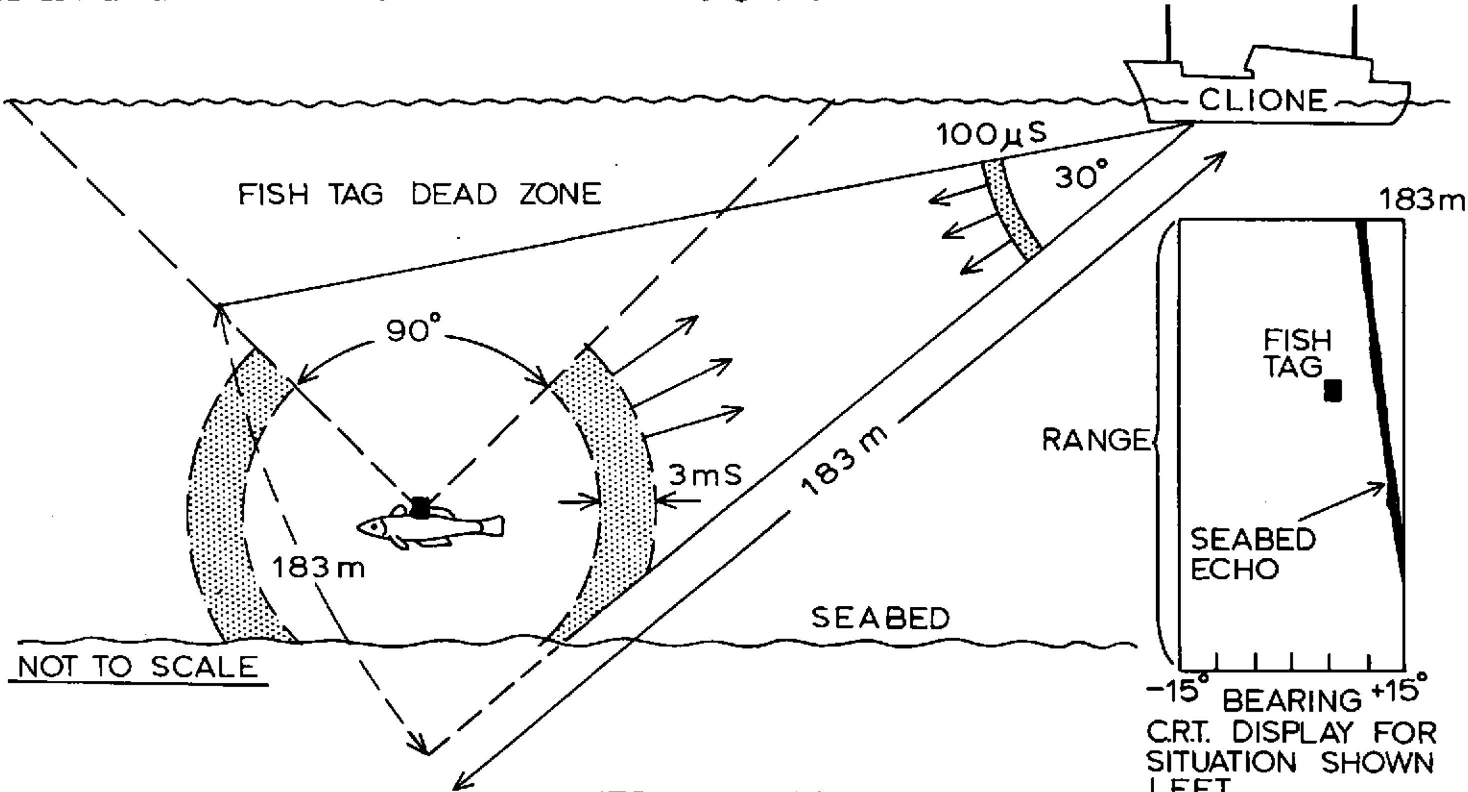
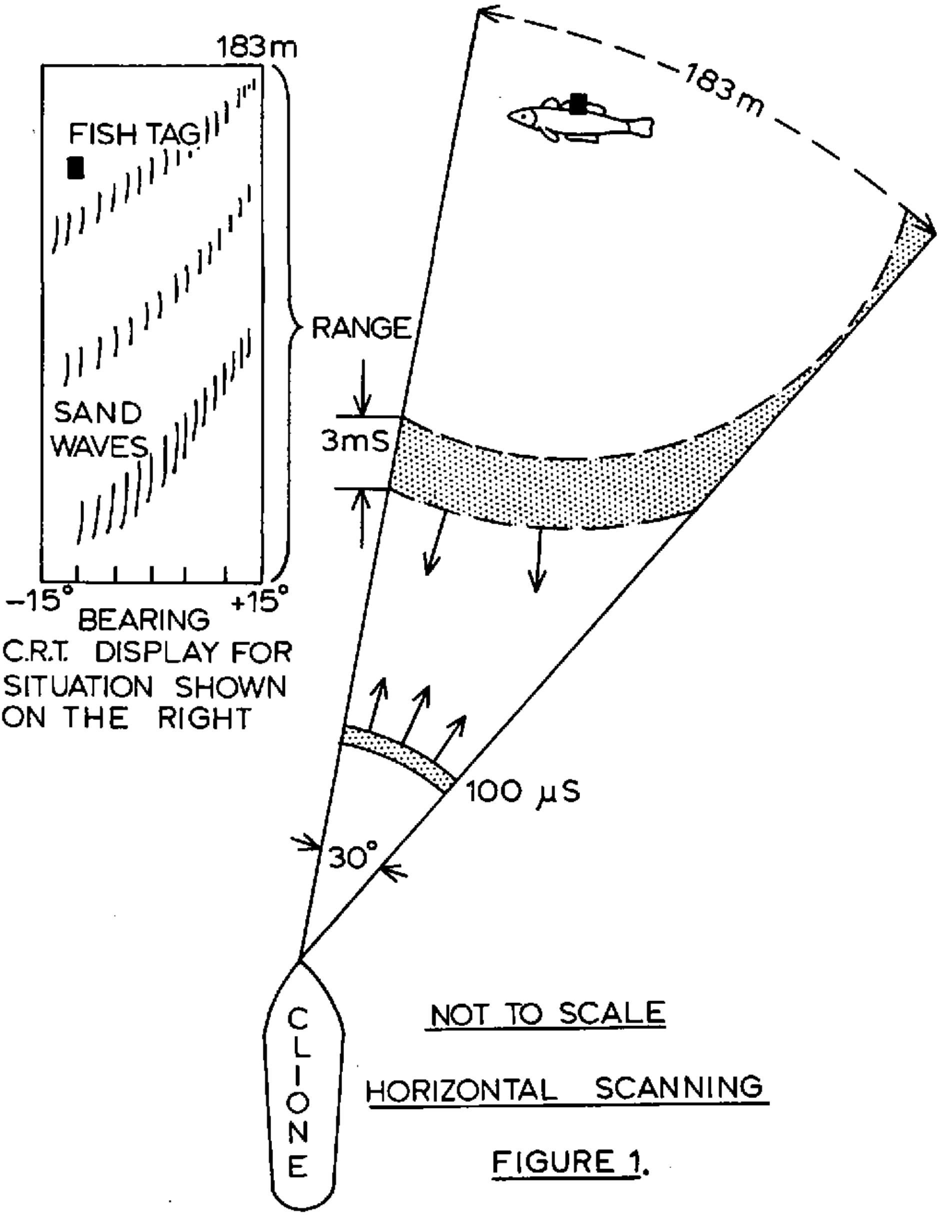


FIGURE 2. VERTICAL SCANNING



HORIZONTAL SCANNING

FIGURE 1.

Two further stages, VT7 and VT8, are connected as a Darlington pair to switch the oscillator section, VT9 and VT10. The output pulse, 3 ms long, is coupled by a small ferroxcube cored transformer to the transducer. VT11 and the gate source diode of VT1 are connected in such a way as to protect the receiver from high voltages generated during transmission.

Electrical performance

Detailed information on fish movements is required, so the interrogation rate is high (2 or 4 times per second). This means that demand on the battery is relatively high and has two components, the current needed to maintain receiver sensitivity and the transmitter current during the pulse. Three mercury cells are used, each having a nominal voltage of 1.4 and an 85 mAh capacity at a 1 ma rate. At the 4 times per second rate of interrogation the battery has a life of 32 hours, which is adequate for the work being carried out at present. An increase in battery size would extend the life of the tag but would limit its use to rather large fish. The present three cell battery weighs 3.1 g in air; it measures 1.6 cm in length by 0.77 cm diameter, thus making up one-third of the total volume of the tag.

A continuous drain of 500 μa is due to the receiver, this section having an input sensitivity of 5 μv for positive triggering of the transmitter. It is tuned to 305 kHz and has a bandwidth of about 7.5 kHz, with an overall gain of 90 dB.

The transmitter has a quiescent current of 12 μa; during the 3 ms pulse period it draws heavy current from a 68 μ capacitor across the battery supply. Measurements of the acoustic source level show that this is +47 dB/μbar/m.

Construction and assembly

The uncased battery, electronics and transducer are 4.7 cm long x 0.8 cm diameter; they weigh 5.5 g in air. A method of encapsulating the assembly was developed which added only 1 g to the basic weight, giving a weight in sea water of 3 g. However, for experiments carried out up to the present time it has been found convenient to place the assembly inside the modified body of a disposable syringe; these items are made of polythene with a 1 mm wall and have an internal diameter suitable for the tag assembly. The only disadvantage is that the weight then becomes 9.8 g in air, 4.4 g in sea water. A small disc seals the case and has two terminals projecting; when these are connected together the tag is switched on. The nylon used for attaching the tag to the fish is also fastened to these terminals.

There are three assemblies that go to make up the complete tag, these being the battery, the electronics and the transducer (Fig. 4). The cells of the battery are joined by sticking them together with a silver impregnated epoxy resin. All the other joints in the system are soldered. Most of the components are attached to the 68 μ storage capacitor which is connected across the batteries; this is a plastic-encapsulated tantalum capacitor, rectangular in shape. After the components have been positioned they are wired up with a fine gauge of self-fluxing copper conductor.

Although a high density of component assembly is achieved, layout is important but not critical. Chip capacitors are used where possible and these have helped to reduce the size of the electronic assembly, but it is the resistors which are of particular note. These are of a high stability

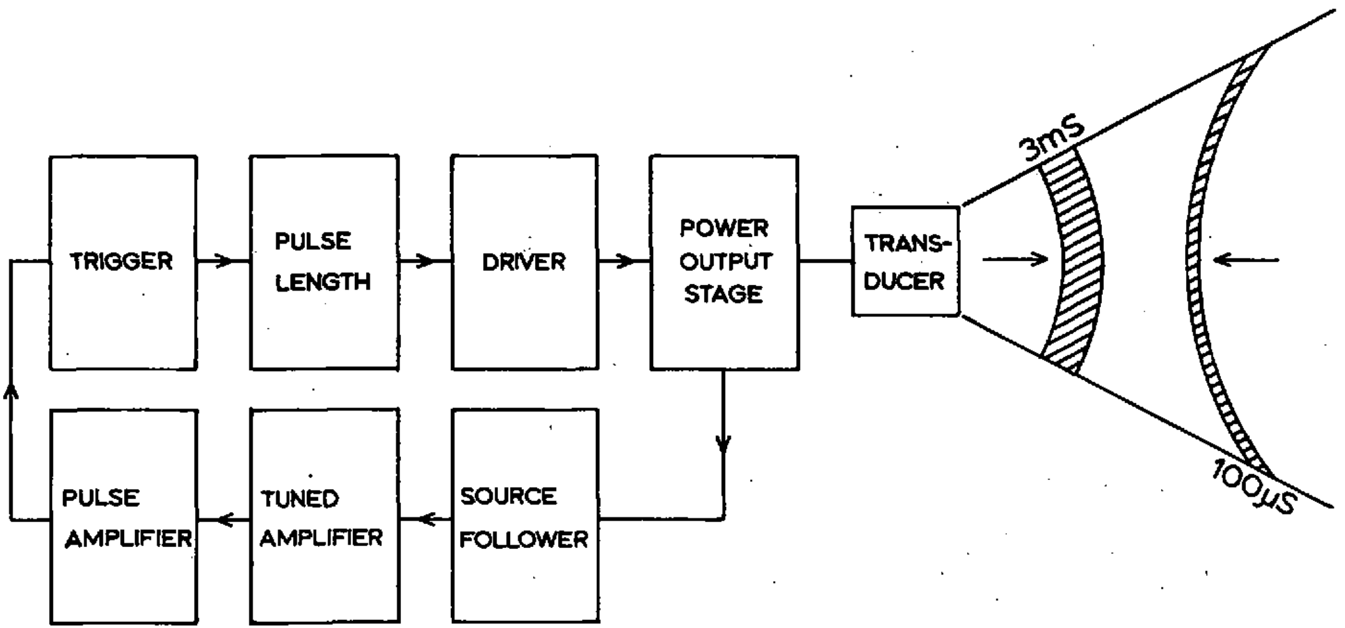


FIGURE 3. BLOCK DIAGRAM: TRANSPONDING ACOUSTIC FISH TAG.

carbon film type, 0.102 inch long x 0.035 inch diameter, used here in values from 10 kΩ to 4.7 MΩ. The transformer and the receiver coil are wave-wound on to ferrocube rods, which are then impregnated with a silicone varnish and stuck in position at either end of the 68 μ capacitor, but spaced by polythene discs.

Finally the transducer cylinder is fixed to nylon support pillars by means of a rod of closed air cell neoprene pushed through its centre and the pillars attached to a disc of jointing material. After testing, the electronic assembly is joined to the battery with a suitable adhesive.

Trials

The first observations were carried out after tagging and releasing a large plaice (Pleuronectes platessa L.) in the Shipwash-Inner Gabbard area of the North Sea. A normal Petersen tag was attached to the fish and the acoustic tag was tied to this by means of a short length of monofilament nylon. The depth of water in the area is about 27 m and the seabed is largely sand and gravel.

To obtain the position of the fish relative to the ship, a log was kept, recording the range and bearing of the tag signal. Then, by logging the bearing of the ship's head and fixing its position by Decca Navigator, the fish's track was built up. Tracking of this particular fish covered a period of 15 hours, being finally terminated by operator fatigue. Preliminary results have been reported in a letter to Nature(4).

Conclusions

It has been shown that the combination of a high resolution scanning sonar and a transponding acoustic tag is a powerful tool for fisheries research. Although this particular combination gives very detailed information for the situations likely to be encountered in the sea there is no reason why the transponding tag should not be used successfully with simpler shipboard equipment. For example, range and bearing are the measurements of interest when tracking fish in most rivers and in this case a small manually-operated transducer with suitable transmitter, receiver and display or recording units would be adequate.

References

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the most important being the propagation losses in sea water. In this application the sum of the spreading loss and the absorption loss make up the total propagation loss for all practical purposes. Because there is a transmitter and receiver at each point, i.e. the ship and the fish, one-way loss only has to be considered. The acoustic properties of the tag must be such that the sensitivity of the receiving section is adequate to detect the pulse from the ARL scanner to the maximum range of 370 m. The acoustic pulse then transmitted by the tag must be sufficiently powerful to be detected with a good signal to noise ratio by the ship's scanning sonar. For the first trials a pulse length of 400 μs was transmitted from the tag. Although the signal from this pulse showed up as a bright spot on the CRT display difficulty was found in distinguishing it from other high-intensity signals, particularly when the bottom reverberation was high. This was overcome by increasing the pulse length to 3 ms so that the signal appears as a rectangle on approximately 30 lines of the display raster. Because the pattern of this signal is entirely different from that of other signals being received, the operator of the sonar can comfortably observe and track the fish. In sea water the spreading loss for the maximum range, r, is $20 \log r \equiv 52$ dB and that due to absorption is approximately 30 dB, making a total loss of 82 dB. Attenuation at 300 kHz varies a good deal with temperature, but in sea areas of interest to us this is unlikely to change the effective range by more than a few metres.

The ship's sonar needs high resolution within its scanned sector to locate the tag signal accurately, but the tag itself must have the widest possible coverage, and, preferably, omnidirectional characteristics. This would need a spherical transducer with rather careful mounting to avoid masking the signals. However, in the transponding tag a small lead zirconate titanate cylinder has been used. If this is fitted to the fish in such a way that the axis of the cylinder is vertical under normal swimming conditions, dead zones for reception or transmission will appear immediately above and below the fish. These are not important for it is impossible to track the fish from a position directly overhead. In practice, ranges between 140 and 230 m were found to be most satisfactory to give sufficient scope for ship manoeuvre. Tests showed that a range of approximately 450 m could be achieved, although this is beyond the normal maximum range gate of the sonar.

Circuit description

The block diagram is shown in Figure 3. A common transducer is used for both receiver and transmitter. This is coupled into the receiver from a tuned winding on transformer T1 via a small capacitor to the gate of a source follower VT1 which is a field effect transistor. VT1 is connected in this way so that the input impedance is reasonably high, thus allowing low value components to be used which are also physically small. The next stage is VT2, which has a tuned circuit in the collector but is resistance-capacitance coupled to amplifying stages VT3, VT4 and VT5.

At the base of VT4 the time constant is such that rectification and blocking of the signal occurs; from the time that the transmitter is turned on by a received pulse, the receiver is blocked for 25 ms to prevent continuous oscillation. VT5 and VT6 are pulse amplifiers with an R. F. filter between the two in addition to the time constant R10, C8 which largely determines the 3 ms transmission pulse.

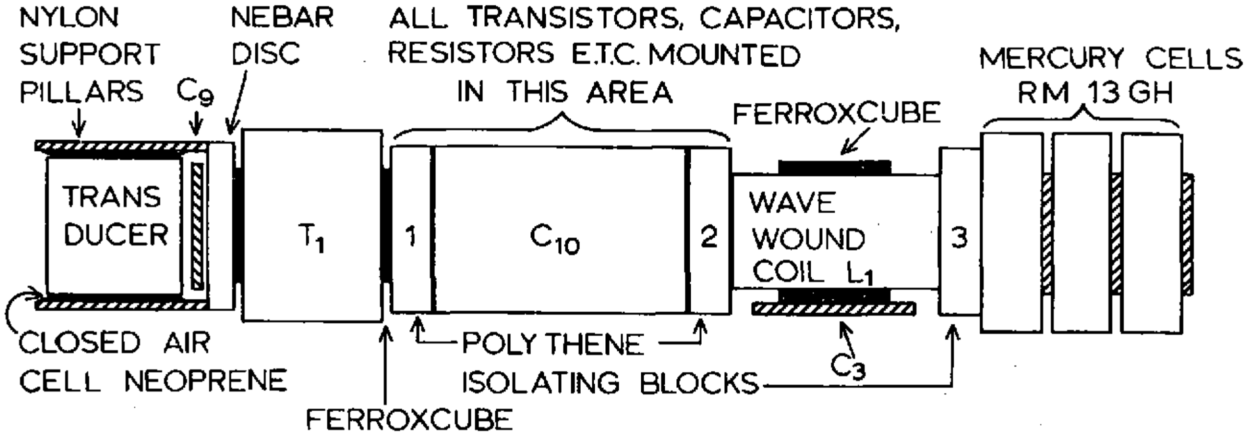

FIGURE 4. COMPLETE ASSEMBLY FOR THE TRANSPONDING ACOUSTIC FISH TAG