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MEASUREMENT OF GEAR AND SHIP NOISE

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A. D. Hawkins and D. N. MacLennan

Marine Laboratory
Aberdeen, Scotland

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Introduction

Most fishing gears are inherently noisy. As a net is towed through the water, vortex shedding and other hydrodynamic effects generate low frequency sounds, while the mechanical parts bang or rattle together. For bottom fishing gears, noise also arises from contact with the sea-bed. The towing vessel itself is very noisy, with the propeller forming a particularly powerful sound source.

The noise generated may have considerable practical significance. It is well established (Hawkins & Chapman, 1970) that commercially important species of fish can detect and react to low level sounds over the frequency range 30-500 Hz, and that they may detect the noise of fishing vessels over considerable distances. Indeed, the efficiency of fishing gears appears to be as much influenced by such behavioural responses as by purely engineering considerations.

This paper describes equipment developed for investigation of the acoustic fields generated by fishing gears, and especially by the otter trawl and its towing vessel. The system is based on a large spatial array of hydrophones laid on the sea-bed, which can provide information on the location of the fishing gear in addition to monitoring the noise field. The techniques employed are of general application, and could well be applied to the study of other fishing methods. Further, our preliminary experiences with the hydrophone array suggest that it may be of value for the accurate tracking of other underwater sound sources, such as fish fitted with acoustic tags.

Two ships are required to make noise measurements on the otter trawl. The first tows the gear under test, and contains a logger for recording data on the physical characteristics of the gear. The second is an anchored and silent listening vessel, containing the signal conditioning and sound recording equipment, and is joined to the hydrophone array by cables.

The hydrophones and recording equipment

The main elements of the signal detection and processing system are shown in Figure 1.

The array consists of up to 20 separate hydrophones, each including a fixed gain preamplifier next to the receiving element. Simple low cost instruments, joined to lightweight cables, are employed since damage to the hydrophone array during trawling must be expected and allowed for. The hydrophones are each mounted within a simple tetrahedral frame, to raise them clear of the sea-bed, and are individually joined to maximum cable lengths of 2,000 metres. The hydrophones are laid from a small launch, and the cables taken to a buoyed line, stretched between two anchored dahns. Each cable is terminated by a water-resistant connector. The cable-ends are connected to the listening ship by an umbilical cord, which can be cast overboard in an emergency.

The connecting cables have four cores, two for signal and two for power. It has not been found necessary to have an overall screen on the cable provided the system is balanced and the following amplifier has a differential input with good common mode rejection. The wide-band electrical noise contributed by a submerged 1,000 m length of cable has been measured, and found to be well below that from the hydrophone preamplifier, and below that equivalent to ambient sea noise at the frequencies of interest.

The hydrophone signals are fed to the tape recorder inputs via a bank of variable gain low-noise amplifiers, which can be adjusted manually. Fourteen tape recorder channels are available and a jack-plug selector panel is provided so that the most useful hydrophones can readily be connected. A microphone, for an oral commentary, a VHF radio link with the towing vessel, and a crystal controlled timer (giving an accurately known series of timing pulses) are also connected to the recorder. A monitor facility is provided so that any input to the recorder, or any recorded signal, can be routed to any one of four separate outputs, for monitoring on an oscilloscope or loudspeaker.

The frequency range of interest for the analysis of trawl noise extends from 1 Hz to 5 kHz. A frequency modulated (FM) tape recorder channel is used to record the noise and provides a good signal to noise ratio and good low frequency performance. However, the methods used to locate the fishing gear require the recorded frequency range to extend to higher frequencies than is possible with FM. Direct record (DR) channels have the necessary high frequency response, but are not as good as FM channels in signal to noise ratio and low frequency performance. These conflicting requirements are met by connecting each hydrophone in parallel to one high frequency amplifier, and one low frequency amplifier. The former drives a DR channel of the recorder, and the latter an FM channel.

The frequency performance and fidelity of recording depends upon tape speed. The higher the speed the better. A limit is set to this, however, by the playing time of the tape - which must last long enough to cover a complete experimental tow. Typically, for a playing time of 60 minutes, an FM channel can cover the frequency range 0-5 kHz while a DR channel extends from 50 Hz to at least 50 kHz. Thus all noise frequencies of interest are recorded on an FM channel, with good overlap for extrapolation to higher frequencies using a DR channel.

Location of the hydrophone positions

Though the hydrophones are each laid with the aid of the listening vessel's radar, it is essential that the geometry of the array should be precisely known. The relative positions of the hydrophones are therefore determined before a run with the trawl by using a synchronised pinger. This instrument emits high amplitude acoustic pulses at a well-defined frequency and pulse rate. It is lowered to the sea-bed at various points around the array, and the differences in the time of arrival of the pulses at the different hydrophones used to compute the array geometry. We have found that this operation is most readily performed by towing the pinger around the array, at a distance of 1,000 m or more from the centre, using a small launch.

Location of the towed fishing gear relative to the array

It is also important during each tow of the gear to determine the position of the ship and gear relative to the array. This is to permit later location of the various sound sources within the gear. The positional information is again obtained using a synchronised pinger, which in this case is attached to the gear at a suitable point (generally the centre of the headline).

The pinger pulses are modulated at a relatively high frequency (20 kHz), which is well above the frequency range of interest for noise analysis. Though at this frequency some interfering noise is generated by the gear, the effects of this are minimised by feeding the tape recorder output through a band-pass filter centred at 20 kHz. The pinger pulses are therefore easily distinguished, and can be fed to a discriminator for timing purposes.

Determination of gear geometry

A number of instruments are attached to the gear to measure its physical characteristics (MacLennan, 1969). The parameters which can be measured include:-

1. Gear geometry, eg vertical netmouth opening, horizontal netmouth opening, distance between the otterboards, warp angles (declination, divergence and heel).

2. Towing loads, eg in the headline and groundrope legs, fore and aft of an otterboard, at the ship.

3. Otterboard parameters, eg angles of pitch, heel and attack.

4. Ship parameters, eg towing speed, engine RPM, propeller thrust.

It is hoped that it will be possible to correlate measured physical characteristics of a trawl gear with the type of noise it produces. In this way it may be possible to isolate specific factors in gear design procedures which, through the sensitivity of fish to gear noise, may affect catching efficiency.

The results of preliminary investigations

Hydrophone arrays have now been laid and operated from an anchored vessel on a number of occasions. These experiments have provided information on the level of ambient noise in the sea, and have also permitted the further refinement of the listening and recording system. More recently an array has been laid from the research vessel "Clupea" on a sandy bottom at a depth of 40 fm in the Moray Firth area, and recordings made of the noise generated by an otter trawl towed by the research vessel "Explorer". The geometry of the gear was monitored throughout each of two towing runs. On one run, the trawl passed directly over the array, striking one of the hydrophones. Good noise recordings were obtained from the experiments and indicate that the noise generated by the particular type of trawl used was substantial. Significant components of the noise can be assigned to different parts of the gear including the boards, bobbins and headline floats.

The analysis of these trawl noise recordings will proceed in a number of ways. By presenting the analysis in the form of a plot of 'isobars' of sound pressure around the gear it may be possible to obtain some idea of herding efficiency. Comparisons of different designs can then be made. It may also be feasible to correlate the signals from several hydrophones to locate specific sources of noise.

We propose initially to perform these analyses by computer. This requires data in a digital form for analysis by program. A fast ADC is required for this, but relatively limited resolution (8 bits or more) is likely to be sufficient. A suitable interface is at present being completed.

References

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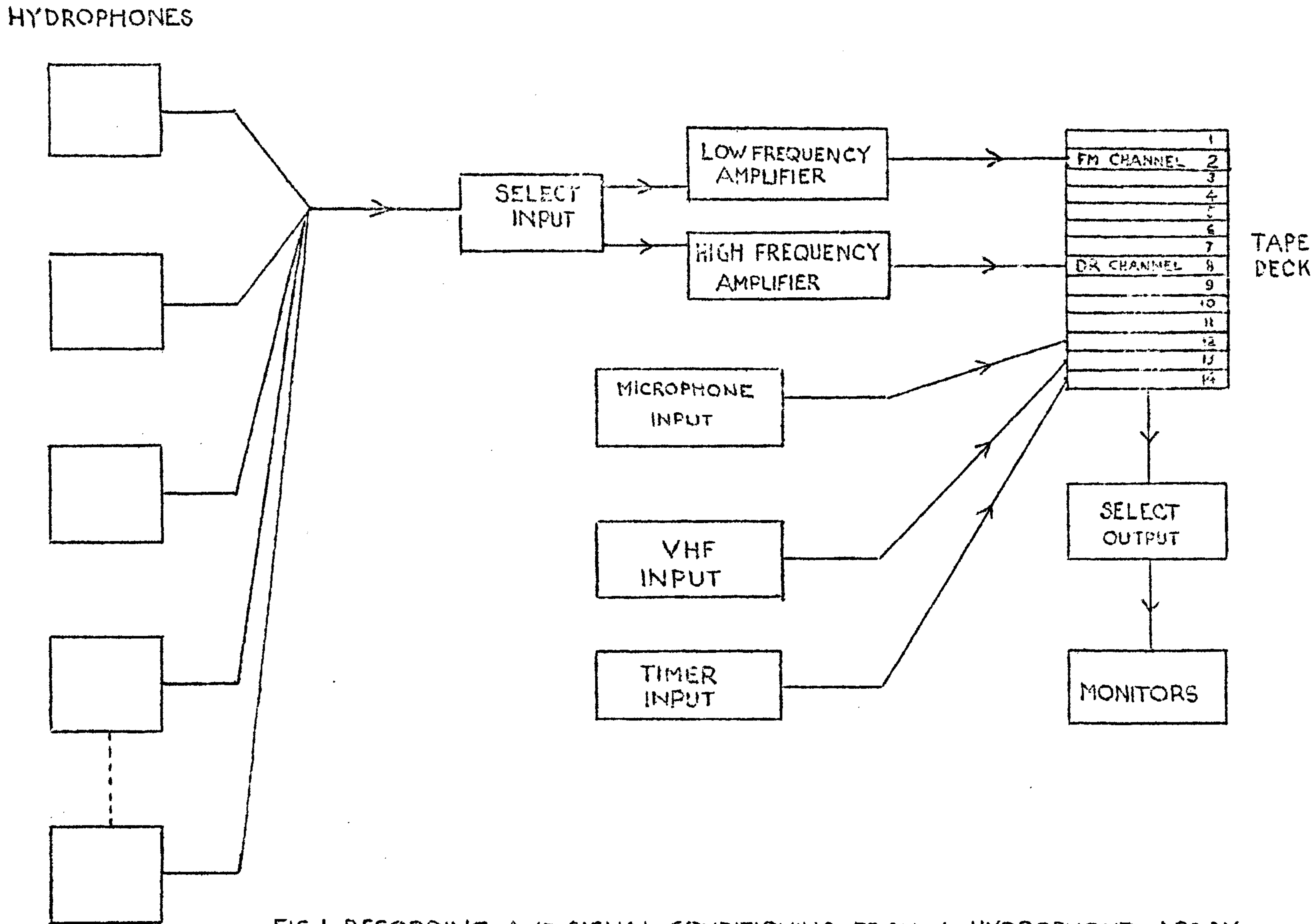

FIG. 1. RECORDING AND SIGNAL CONDITIONING FROM A HYDROPHONE ARRAY