Paper to be presented at the Underwater Acoustics Group of the Institute of Acoustics meeting at the Nautical College, Hull on the 26/27 September 1978 on "Acoustics in Fisheries".

Digital computer analysis of echo sounder data for fish identification.

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Abstract.

Two main advantages of using a computer with an echo sounder are:- 1. the skipper can have much better choice of what information should be displayed and what type of stand-by alarms are required, and 2. the computer is able to make a fine analysis of the echo and to intensify the display of significant echoes such as fish shoals, marking these when possible with information on estimated fish size and shoal density. This paper describes the techniques used for data capture, bottom quality determination, fish and shoal identification, interaction with the skipper, and data display. The computer techniques include sampling and analogue to digital conversion, intercommunicating multiple processors, pattern recognition, self adaptive pattern recognition, correlations, human interface and hard copy and video display. Where possible results of fish target strength data obtained from fisheries research laboratories are used.

Digital Computer Analysis of Echo Sounder Data for Fish Identification

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1. Introduction

The initial motivation for work in this area came from observing commercial fishing activity in the Irish Sea, in particular mid-water trawling for herring between County Down and the Isle of Man. A good skipper can obtain a large amount of information about the fish under the boat from the various displays currently available; however there is still considerable fish stock waste resulting from some boats landing undersize fish, usually sold for fishmeal, and protected species which have to be dumped.

It later became evident that a reliable bottom quality indicator would be of benefit not only on commercial fishing boats but also for research purposes.

It is now well established that microprocessors can easily be used in environments previously considered unsuitable for computers. At the same time as considering replacing conventional electronics with a microprocessor it is reasonable to consider the best way of obtaining additional information and facilities from the system. The needs of the small inshore boat with inexpensive equipment and the larger trawler are both considered.

Some of the concepts discussed in this paper have already been implemented in a working system, others although speculative are thought to be realisable.

2. Aims

The following aims result at least in part from the requirements of research bodies and commercial fisheries interests in Northern Ireland.

2.1. Bottom quality determination

From an initial ability to discriminate mud, boulder and cobble it is hoped to develop pattern recognition techniques to identify a wider selection of bottom types. Some parts of Strangford Lough have been mapped in detail by divers from the Ulster Museum; further dives to 40m and less can be organised as required; Strangford Lough provides a very wide range of bottom types and is sheltered on all sides and is a suitable stretch of water for this work.

2.2. Freshwater fish population assessment

There has been considerable interest for the past ten years in the eutrophication of Lough Neagh, the British Isles largest inland lake; various fish counting exercises have been carried out using chart recording echo sounders. A specific project for shallow water fish counting using a microprocessor system has been set up; the depth distribution of the fish is of particular interest when correlated with the observed oxygen saturation distribution. In addition to supporting a substantial freshwater commercial fishery, the Lough is also used for commercial and civic water abstraction.

2.3. Marine shoal indication

There is a need to accurately assess the type of fish in a shoal in order to avoid shooting nets when the fish are undersize or of inappropriate species. It is anticipated that this particular computer algorithm supplemented with shoal size estimation would be used to appropriately trigger a stand-by watch alarm.

2.4. Display selection and intensification

Time varied gain, "white line" and noise reduction algorithms are readily implemented, but it is also desirable to provide facilities for selecting particular depth ranges and expanded display, and to apply selective image intensification so that the skipper can look for additional information that has not been specifically catered for by program. In the first instance all the display is on a conventional computer video display unit, the only hard copy being obtained by replacing this with a very slow conventional computer Teletype. A chart recorder can be used for output, an algorithm can be readily implemented for displaying text on the chart recorder. When interaction with the skipper is required, a video display unit with keyboard will be incorporated in the system.

3. Techniques

3.1. Acoustics and electronics

To date, a single element PZT transducer working at 150 KHz, 60 watts and variable length pulse has been used together with a National Semiconductor 1812 universal ultrasonic transducer driver chip. A filter and detector unit are constructed with 1322 operational amplifiers. A 4856 sample and hold and a 4114, eight-bit analog to digital converter are used. A new electronics system with 16 element transducer and 12-bit analog to digital converter is currently being designed; the design principle is that the minimum amount of processing possible should be carried out by electronics, giving all possible data processing to program. The echo intensity is sampled at variable intervals, a shorter interval implying that there will be more data to be processed for any given depth. See Figure 1.

3.2. Computers

To date, a single Digital Equipment Co. LSI 11 computer with 8K 16-bit words of RAM and 4K words of core has been used. It has been necessary to calculate program timings carefully in order to ensure that the required data acquisition rate can be maintained; because output is so slow, it has to be done at separate times from the acoustic sampling.

An ITT 3300 terminal with cassette tape was used for program and data storage.

In the short term it is planned to continue using the LSI 11 computer, but at some later stage to replace this with a number of separate microprocessors each dedicated to a particular task and each communicating, when necessary, with the others. A small system for an in-shore boat with only a chart recorder display would probably contain only three or four microprocessors. See Figure 2.

3.3. Programming languages

The number and size of programs has now reached the stage when machine language programming for the LSI 11 is proving to be impractical. FORTRAN programs have been used to process the data that has been brought back to shore, but it has been decided to use the programming language "Pascal" for the development of any further real-time programs; "Pascal" has been chosen since there are suitable extensions, with working compilers, for multimicroprocessor systems.

3.4. Programs

The following programs have been implemented:-

Single pulse data collection.

Multiple pulse data collection.

Depth indication.

Statistic properties of bottom echo and reverberation.

Bottom quality indication.

Autocorrelation for periodic noise reduction.

Midwater target indication.

Numerical and text display.

It is hoped to extend these in the near future to provide:-

Fish counting for isolated fish

More extensive bottom quality indication.

Automatic optimising to allow new bottom types to be added to the bottom quality menu at sea.

Chart display.

And then to include:-

Shoal type indication.

Automatic optimising to allow new shoal types to be added to the menu at sea.

Display range, sensitivity and discrimination selection at sea.

Alarm selection.

3.5. Pattern recognition techniques

The aim of the pattern recognition techniques used is to discriminate between events, which are characterised by various numerical parameters, with a minimum amount of computation. The weights applied to the parameters depend on which discrimination is being tested; the weights may either be applied at program design stage, or by using a real time optimising technique which maximises the significant features of the known events; once the weights have been determined for the known events, these are applied to the actual data to determine the most likely correlation with one of the known events.

Figure 3 demonstrates one technique in a simple form with only two parameters, called m and n, and 3 known events A, B and C. In the first place A is distinguished from B and C by giving a very low weight to parameter m, then if the actual data is found to lie within the B/C zone the discrimination between these is made by giving a high weight to parameter m; for instance, actual data at X would be indicated as being a 'C' type of event. The parameters are multiplied by the weights and summed to give a numerical value for the discrimination; the weights are chosen when possible to be integer powers of 2 in order that the computer arithmetic can be implemented with shift functions ~~which~~ because multiply functions tend to be very time consuming on microprocessors.

In a practical case, more than two parameters are used; the weights are chosen so that the parameters which fluctuate significantly in echoes from a fixed target are minimised, unless this fluctuation is a significant property of the target.

The weights and discrimination levels can be assigned by the programmer when the differences between different target types are known in advance, as for instance, in the primitive bottom type determination. Once incorporated in a program this pattern recognition algorithm could not be changed; there is a strong motivation for ensuring that the weights and discrimation choices, as well as the program itself, are correct since they cannot be changed at sea.

A further development is to allow new events to be specified at sea; the programming techniques are similar to those used for speech recognition; the major technical difficulty appears to be that it is difficult, though not impossible, to reliably store information whilst a microprocessor is switched off; it would be undesirable for a skipper to have to re-initialise the menu of events every time he switched on the instrument.

The weights attached to the various parameters would obviously depend very heavily on the type of transducer being used, in particular it's frequency and beam width; for bottom quality determination the magnitude of the transducer's side lobes would also be significant.

3.6. Microprocessor application

Microprocessors can readily be made sufficiently rugged for marine applications. They tend to be slow and the pulse repetition rate should be as fast as possible, it is therefore necessary to consider configurations with multiple microprocessors each performing a simple task rather than aim to time share one single processor. For instance, in a basic system there would probably be one microprocessor which only collects the values of the received echo intensity at fixed intervals, say every 40µs; and distributes the values to the others; another microprocessor would probably scan this data to determine the bottom depth and possibly apply "white line" discrimination and indicate to the first when to transmit the next pulse; a separate processor would be searching for midwater objects; another would be controlling the chart recorder.

Additional facilities could be introduced by the addition of extra microprocessor modules, including one perhaps to control a keyboard and visual display unit.

The design and programming of multiprocessor systems is a research topic under investigation at Queen's University.

The programs would be "hard-wired" into the microprocessors in the first place using field programmable read-only-memory (ROM), but for production runs would be included in the final mask stage of the chip production. This type of application of computers, therefore, needs particularly well written and reliable programs since there is no means of changing them if ever a mistake is found! It is, of course, also necessary to write correct constants, weights and so on into the ROM.

3.7. Display

Considerable thought must be given to optimum data display; in the first place the equipment would probably be an addition to existing instrumentation; where no interaction with the program is needed, an existing chart recorder programmed to also print messages would seem to be the appropriate display device. The use of a colour television screen, as on the Simrod "Integrated Data Display", would be something to consider at a later stage.

4. Future development

A number of shortcomings have been highlighted by the small project that has been completed to date, including for instance, the need for a more sensitive analog to digital converter, see Figure 4. The plans at present are to extend the program repertoire, as indicated in section 3.4, using the existing LSI 11 computer on a time shared basis but to change to Pascal as the programming language and use re-designed electronics with a 12-bit ADC and the transducer array discussed in section 3.1. Tentative plans exist for collecting the data with 16-bit accuracy.

As a concurrent project it is planned to develop the existing system for Lough Neagh fish stock estimation, and to consider the needs of a cheap system for in-shore herring fishing.

A further plan is to develop the multimicroprocessor design so that the pulse repetition rate can be speeded up.

Digital processing of side scan data is being considered.

5. Acknowledgements

I would like to thank:-
The Computer Science Department at Queen's University for encouragement and financial support.

The Department of Agriculture for Northern Ireland for employing a student to work on the project during the summer vacation.

The Marine Biology Station fo Queen's University for laboratory space and for time on the research boat "Nerilla".

The Biometrics Department at Queen's University and the Northern Ireland Freshwater Biological Investigation Unit for interest and encouragement.

6. References

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Various internal reports on program correctness and multiprocessor systems produced in the department of Computer Science, Queen's University.

Simrod research project: integrated data display for fishing vessels.

J.M.C.

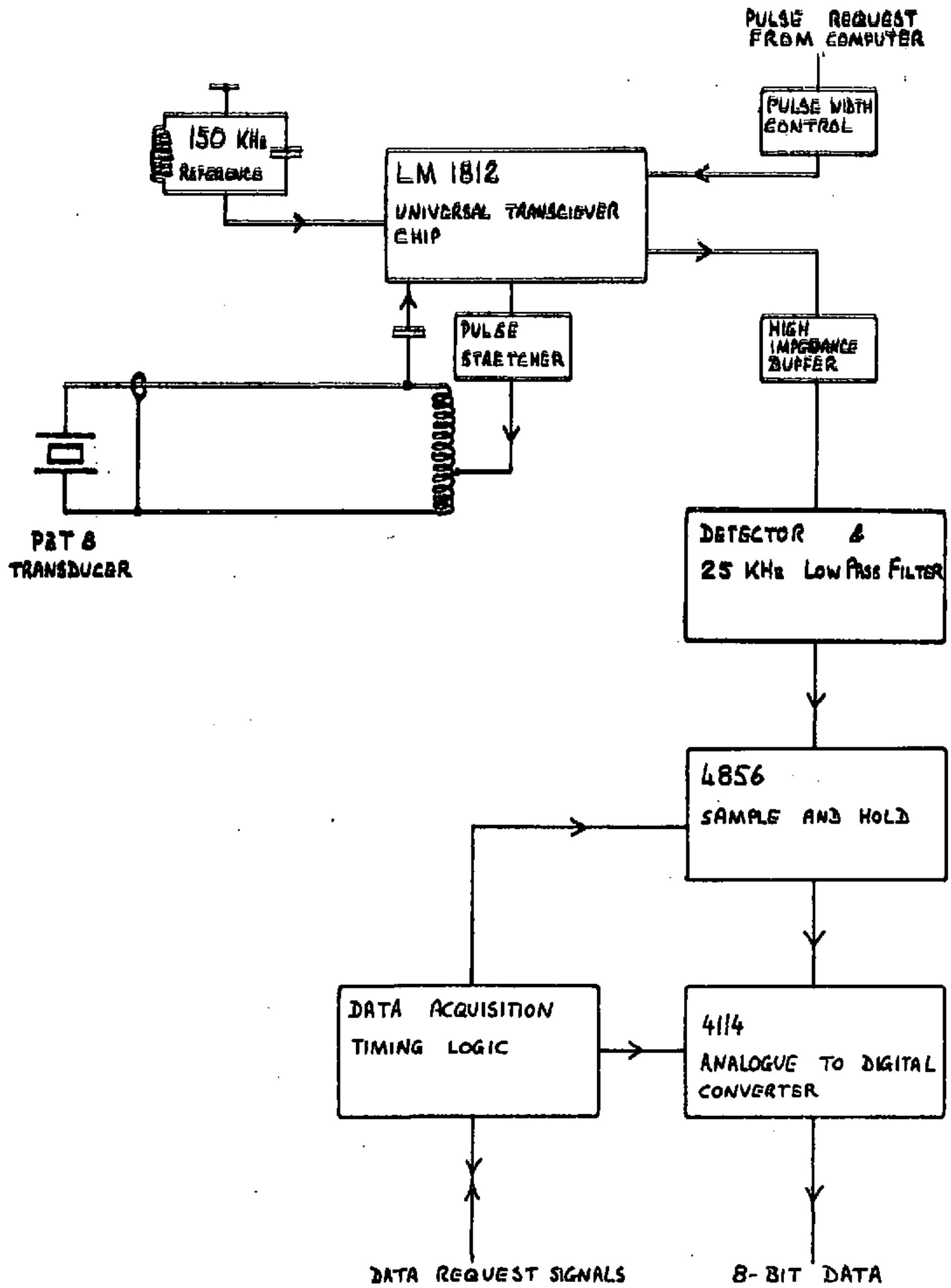


FIGURE 1 ELECTRONICS

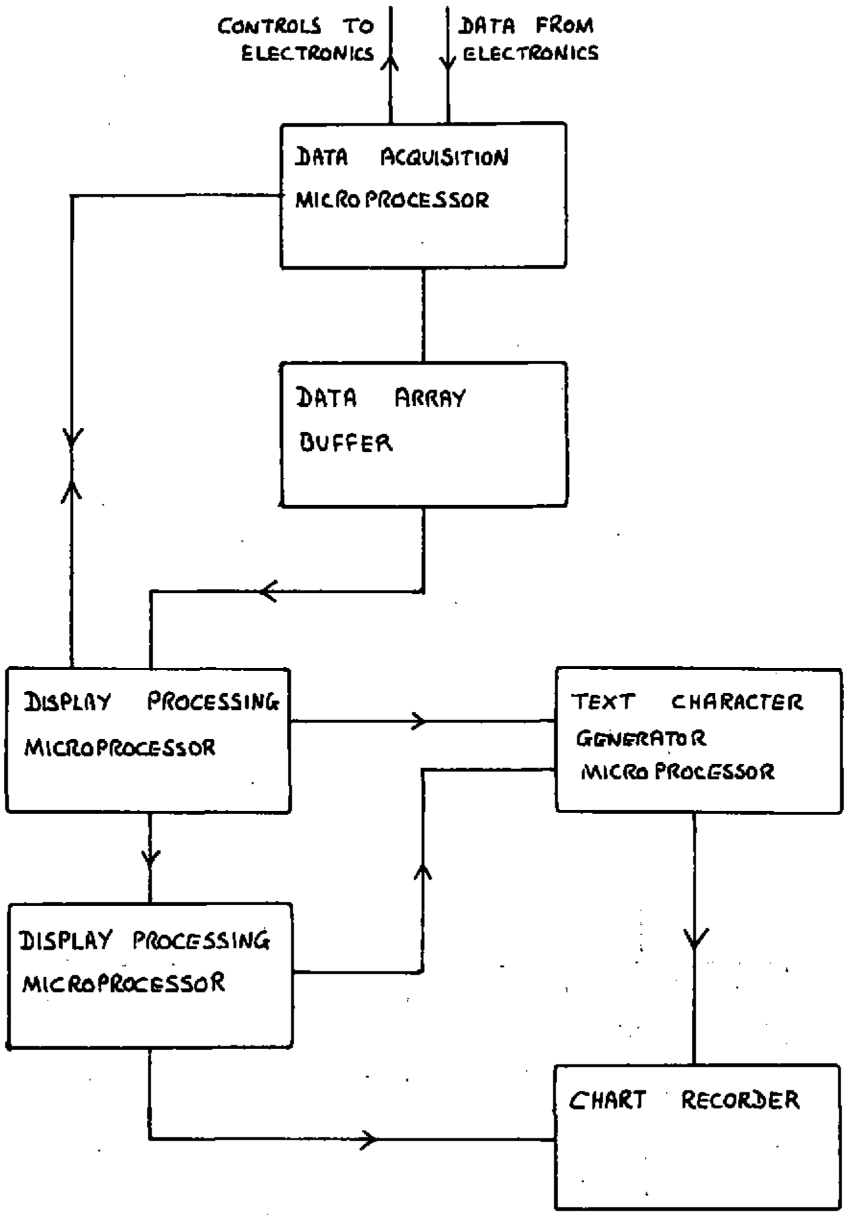


FIGURE 2 SCHEMATIC MULTI-MICROPROCESSOR SYSTEM

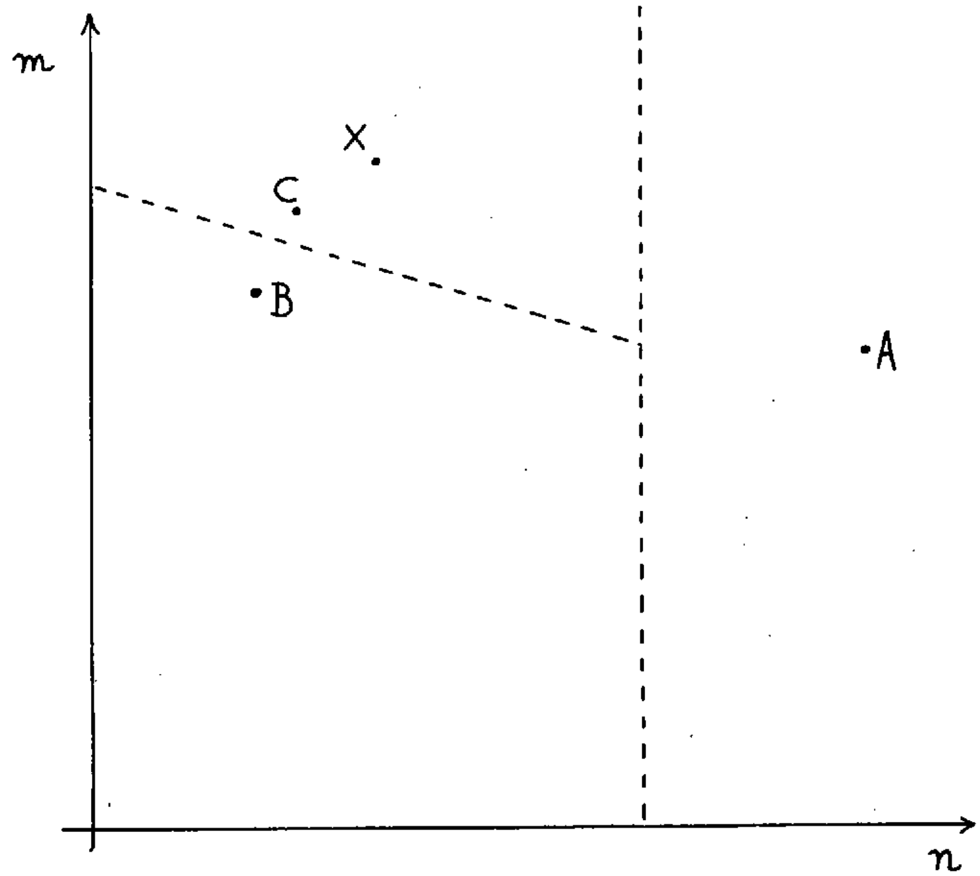
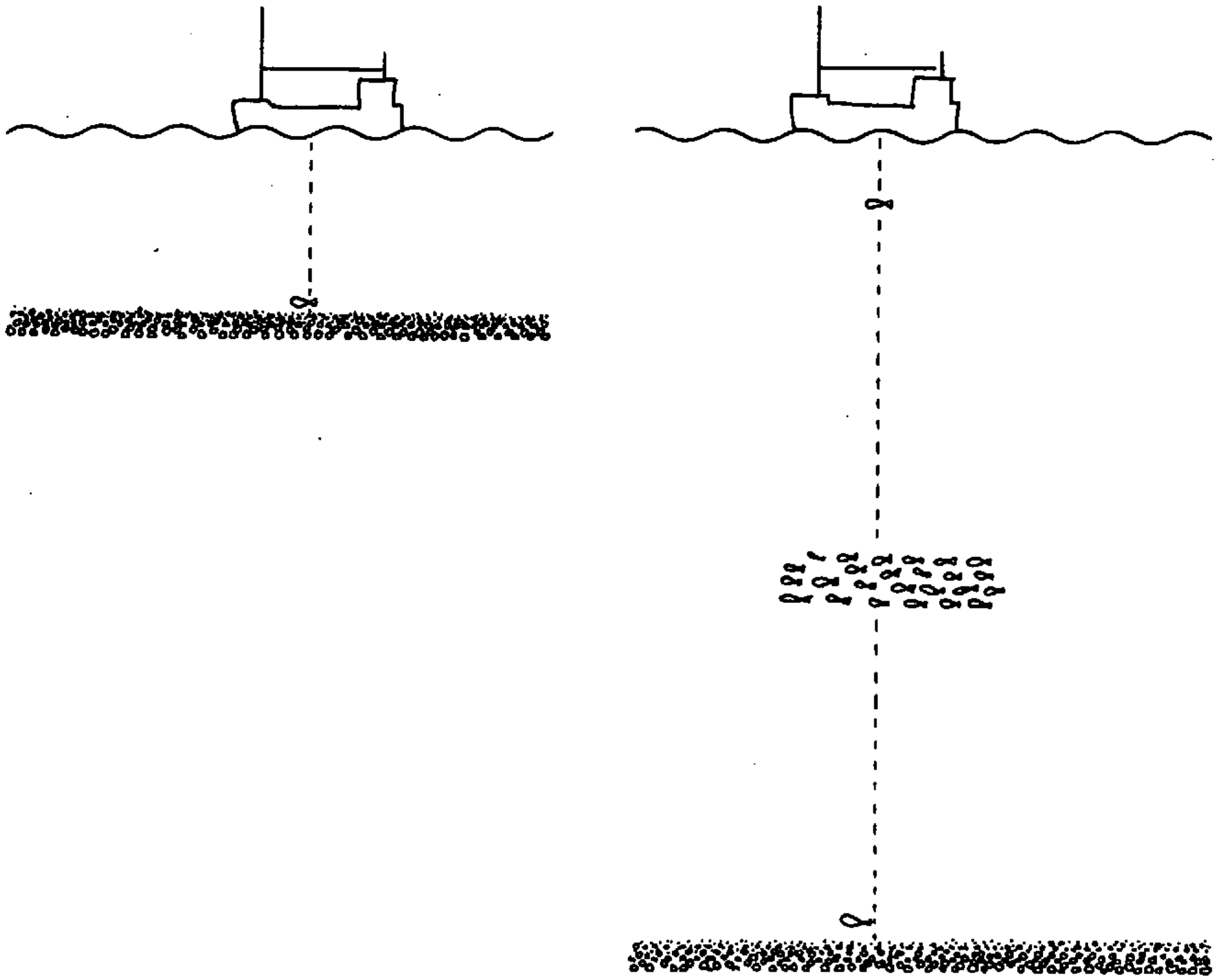


FIGURE 3 ELEMENTARY PATTERN RECOGNITION



MINIMUM SIGNAL DISCR.		-103 dB	1 bit
A	FISH AT 5 m.	-58 dB	16 bits
B	MUD AT 5 m.	-15 dB	30 bits
C	FISH AT 2 m.	-42 dB	21 bits
D	SHOAL AT 20 m.	-53 dB	18 bits
E	FISH AT 40 m.	-97 dB	3 bits
F	MUD AT 40 m.	-36 dB	23 bits

Based on need to detect fish at 40m, and not to saturate A.D.C. in shallow water

FIGURE 4 RANGE OF ANALOGUE TO DIGITAL CONVERTER