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A PC-based echo integrator system appliable for school structure analyzis

by

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Abstract

A low cost system for integration of echo signals on a PC has been developed. The system calculates the area backscattering strength in surface and bottom layers, and is designed both for the purpose of conventional acoustic abundance estimation and for quantification of fish school structure. The system has been installed onboard R/V "Fjordfangst" (20 GRT), and echo integration trials of herring schools have been conducted in Northern Norway. These measurements revealed great variations in internal packing density of the schools.

Introduction

Application of modern computer technology has promoted improved and sophisticated echo integrator systems for acoustic abundance estimation of fish stocks (Bodholdt et al. 1988; Dawson, Brooks and Kuehl 1989; Diner et al. 1989; Knutsen 1989; Dengbol et al. 1990). Especially the flexibility of the systems is increased to give the opportunity of a more objective judging process. Systems for computer processing of echo signals have also been developed for special purposes such as quantification of vertical distribution of biological scatterers in lakes (Megard et al. 1989) and of fish in aquaculture cages (Floen et al. 1988).

Much effort has been given to understand the structure and function of fish schools (Breder 1951; 1959; Keenleyside 1955; Shaw 1969). Detailed 3-dimensional studies of the internal organization (Cullen et al. 1965; Partridge et al. 1980; Partridge and Pitcher 1981) changed the impression of schools as well-structured, egalitarian units towards a recognition of schools as being composed of dynamically behaving individuals (Partridge 1981; 1982; Pitcher 1986). These studies were conducted on enclosed schools in aquaria conditions, and except for the investigations by Graves (1977) and Serebrov (1976; 1984), little quantitative information about the internal structure of free-swimming schools exists. The need for such knowledge is increasing in connection with methods for monitoring the abundance of schooling species by use of sonar (Hewitt et al. 1976; Misund et al. 1989).

For fish behaviour studies in situ, the low visibility underwater forces often the use of acoustic instrumentation. The resolution of such systems is generally rather low, which gives great distortion of school shape (Misund 1990). Johannesson and Losse (1977) outlined a method for quantification of the average school structure by use of conventional echo integration systems. Cushing (1977) studied the structure of pelagic herring and sprat schools by a high resolution, scanning sonar, but such equipment gives the distribution of the individuals in two dimensions only.

Applying contemporary computer technology, we have developed an inexpensive echo integration system for fish abundance measurements. For school structure studies, the resolution of the system is improved by options for producing output at short intervals, both in the horizontal and vertical scale. The system is designed to handle and store large amounts of echo signal data that is easily accessible for manipulation and statistical and graphical processing. The applicability of the system was demonstrated when used for quantification of the structure of herring schools.

System description

The hardware of the system consists of a demodulator/signal converter and a main processing board with a sample and hold cirquit, analogue to digital converter, microprocessor, multiplier and memory. The hardware was developed as part of a thesis at the University of Oslo (Abrahamsen 1988). The demodulator is external to the IBM PC and is the interface between the signal source and the main processing board inside the PC. The main purpose of the demodulator is to convert the high frequency AC signal to a positive envelope curve. Valid input signals are +- 10V and frequencies are in the range of 10 – 600 kHz. The demodulator also has inputs for positive and negative trigger signals.

Both the S/H cirquit and the A/D converter are parts of the main processing board. The S/H used is Analog Device AD585, which is a high speed S/H amplifier with aquisition time of 3 µs. The A/D converter is Analog Device AD574A, which has 12 bits resolution (2.5 mV/bit). The convertion time is 25 µs which gives a maximum sampling rate of 40kHz. The main processor is an 8 bit Motorola 65C02, as multiplier is used Analog Device ADSP1012A, with a 12 x 12 bit parallell multiplier. The memory consists of 8k SRAM and 8k EPROM.

All I/O handling to the processor is controlled by a 65C22 VIA circuit which also contains two timers. The 65C22 reads the echo trigger signal which start the A/D converter, and the log puls (200 pulses/nautical mile) from the main ship log. This circuit also controls the milemarker of the echo sounder. The echo integration starts when the processor gets the trigger signal and starts the A/D converter. Timer one on the 65C22 controls the sampling frequency on the S/H cirquit. The converted signal from the A/D converter is clocked directly to the multiplier, and after ended quadration and summation transferred to the memory. Timer two on the 65C22 controls the start and stop of integration in a selected interval.

The software conducting the echo integration is divided in two distinct parts. Sampling of the echo signal and the actual integration is done by a 65C02 assembly program on the integrator card. The user communicates with a program written in PASCAL on the PC. This program controls the integrator card and does the final calculations on the echo data, as well as presenting and storing the results.

When echo integration starts, the integrator card gets the definition of the surface- and bottom related layers from the PC. In addition several other parameters describing how to do the echo integration is transferred. This includes noice level, how to detect bottom, integration interval, maximum depth for bottom detection and how often it is permitted to loose bottom detection. The trigger signal of the echo sounder starts the sampling of each ping. The quadrated echo signal is sampled at 20kHz and accumulated for every layer until the integration interval has been reached, or the number of pings has exceeded the maximum of 255 pings. Integration interval can either be governed by number of pings, or on sailed distance based on input from the ships log. Bottom detection is done by interrupt from the bottom pulse of the echo souder, or by a simple software detection algorithm which find bottom when the echo level is higher than the selected threshold for a given amount of time. When the program looses track of the bottom, it will try for a selectable number of pings to find bottom. If this fails, it will abort the current integration interval and report to the PC, before beginning a new interval. When an integration interval is finished, the squared and accumulated echo signals for each layer are transferred to the PC using interrupt. Information on status, depth and actual log interval is also transferred. When this transfer is completed, the program starts on the next integration interval. At the same time a marker pulse to the echo sounder will be generated, making it possible to see the integration intervals on the sounder. Integration continues until the 65C02 is interrupted by the PASCAL program on the PC.

The user interface on the PC is based on a menu system controlled by a trackball or mouse. This was constructed using a Norwegian made object oriented design tool called MOSAIKK. It made it possible to construct the whole user interface separately. All menus, texts, icons, inputfields and boxes were defined and associated with appropriate actions based on events like mouse clicks and keyboard entry. Behaviour of the menu system could then be tested before the program itself was developed. The link between the user interface (called a design) and the program is first established at runtime, when the design is loaded by the program. When some user action indicates that the program has to do a job, the design sends a message to a messagehandler in the program. Based on this message the handler decides the appropriate action, like starting a procedure or reading data from an input object.

Before starting the echo integration, the user will select the menus for setting the operating parameters of the PC integrator. This includes calibration data necessary for the calculations, comments, whether to normalize to one nautical mile, layer definitions, other data needed by the 65C02 program to do the processing of the echo signal, and where to output the results. These settings are saved in a file when the echo integration is started, so that the same settings will be active the next time the program is run. In addition, up to four extra settings can be saved for later retrieval. When the user starts integration, the program will transfer the appropriate parameters to the integrator card, by interrupting the card. The program will then wait for an interrupt from the card, indicating that echo data are available. Using the returned data, the program calculates the M and Sa values for each layer. Since the 65C02 program only returns the total number of pings and log pulses for the whole integration interval, the calculations has to be done using the mean value of the PRF and speed. This does not affect the results, unless the speed or PRF varies significantly during the integration interval. A fixed speed supplied by the user will be used in the calulations if the number of pings is used to control the output interval from the card.

Status, number of pings, PRF, speed, depth, and M and Sa values for all layers, are displayed on the screen for each integration interval. Binary files are used for storing data, if the user save the results in a file. Reduction of disk consumption was the reason for not using ASCII files for data storage. One menu choice converts datafiles to a format readable by the spreadsheet program EXCEL. All information on settings and integrator results will then be available for further calculations and presentation. At any time during integration, the user can select whether to have the results output to printer or not. If necessary, the settings and data can be read from the binary files and output to a printer later on, by using an external program developed for this purpose.

School structure analyzis

The system was installed onboard R/V 'Fjordfangst' (20 GRT) in summer 1989, connected to the vessel's 38 kHz Simrad EY 200 echo sounder, and calibrated according to standard procedures (Foote et al. 1987). In October 1989, the system was used to quantify the packing density and internal structure of herring schools in Gratangen, Northern Norway. Conversion to real fish density was done by applying a 20 log L-71.9 target strength relationship (Foote 1987).

The packing density of 79 schools was recorded according to the method of Johannesson and Losse (1977). The prematuring, non-feeding herring of 33 cm average length schooled in packing densities from 0.4 to 7.8 fish/m^3, with an avarage of 1.5 fish/m^3 (standard deviation = 1.1 fish/m^3).

The internal structure of 20 selected schools was quantified by setting the PC-integrator to produce outprints at every third ping (Fig. 1). Depending of the pulse repetition rate, this gave outprints at horizontal intervals from 3.7 to 16.7 m (average = 3.88 m, standard deviation = 0.66 m, N = 12835). The vertical scale was covered by 15 pelagic channels, set with equidistant intervals from 2 to 7 m, to cover the vertical extent of the schools completely.

The 'cell-integration' revealed a surprisingly large variation in the internal packing density of the schools. The packing density varied from 0.1 to 24.0 fish/m^3 of different integration cells within the same schools, and distinct regions of high and low packing density were apparent (Fig. 1). Empty internal regions and a very uneven outer surface with inward and outward bends, were common features of most schools recorded.

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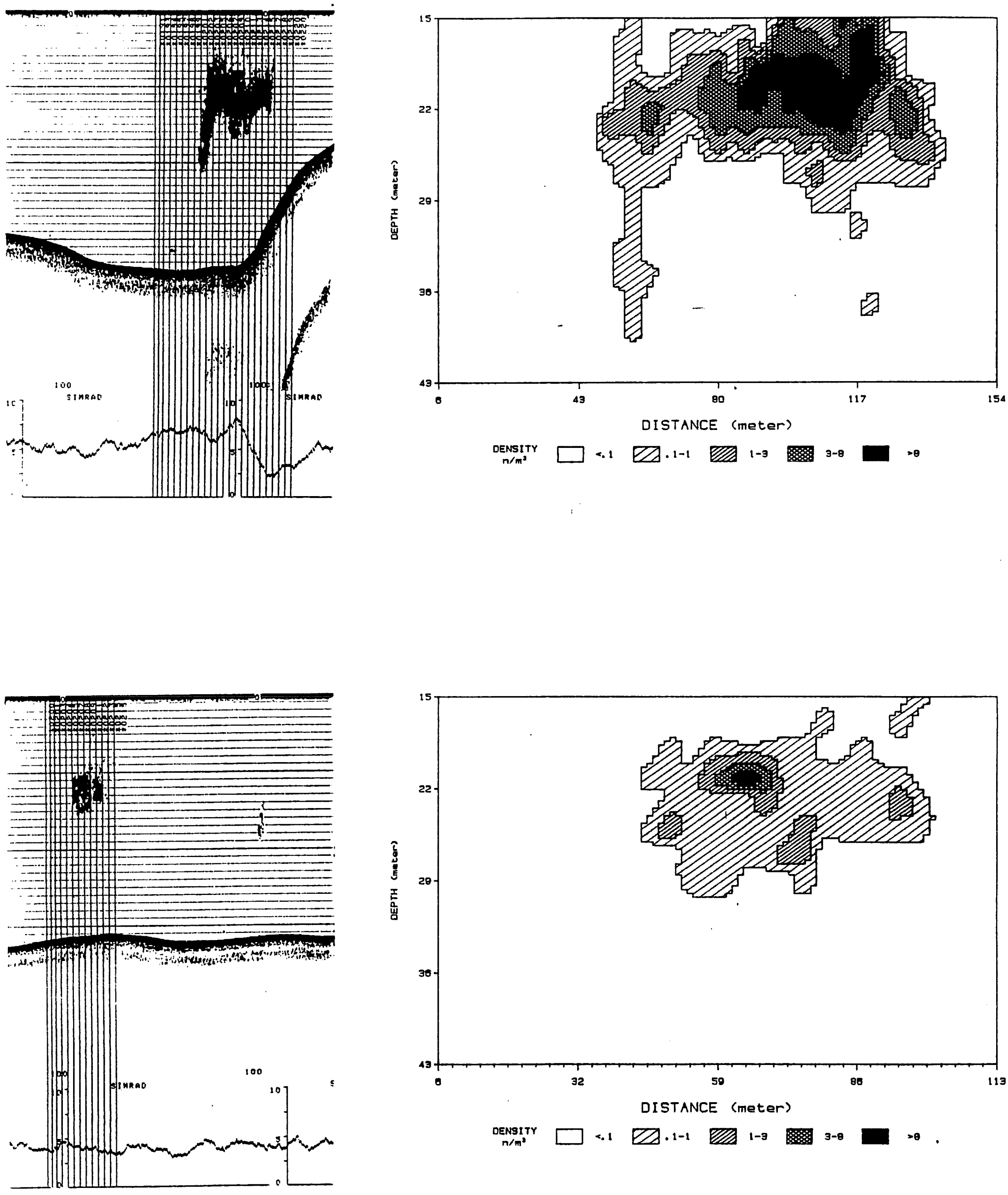

Figure 1. Packing density structure of two 'cell-integrated' herring schools, Northern Norway 1989. Echo sounder recording to the left, and estimated packing density structure to the right.