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AN INNOVATIVE ACOUSTIC SIGNAL PROCESSOR FOR FISHERIES SCIENCE

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INTRODUCTION

The equipment for scientific fisheries acoustics has experienced a revolution in technology in the past three decades. In the 1960's, solid state transistor circuits replaced vacuum tubes, allowing design of smaller sonar systems with improved accuracy, linearity, reliability and stability. In the early and mid 1970's, digital electronics and microprocessors were invented, leading to real-time processing in fisheries acoustics. While smaller and effective, these dedicated microprocessors were single purpose machines with frozen designs and capabilities. The advent of the personal computer in the early 1980's has motivated the development of a new signal processing system by BioSonics, Inc. (Seattle, Washington) called the Echo Signal Processor (ESP). This paper describes the design and use of the ESP.

DESIGN OF THE ESP

A large number of parameters are required to tailor acoustic signal processing functions to a wide variety of scientific experiments. These parameters can be hard-wired into a system to make it easy to use, but at the cost of vastly reduced flexibility. The ESP was designed to provide the fisheries scientist with a tool that is versatile, easy to understand and use, cost effective, and open-ended in its expandability, capabilities and performance. It consists of signal processing hardware and a user interface software package.

Hardware

The hardware is comprised of: a) a circuit card installed in an 8-bit bus slot inside an IBM-compatible Personal Computer (PC); and b) an external signal conditioning pod (Figure 1). The recommended requirements for the ESP computer are: 512k memory (320k minimum); DOS 2.0 or higher; hard disk and one double-sided disk drive (minimum 2 double-sided disk drives); and graphics adapter card with graphic monitor. The signal conditioning pod conditions analog input signals, and outputs various digital markers. It also provides over-voltage protection to the ESP main board, and contains sample and hold and multiplexing devices for the sampling process.

To simplify hookup of the ESP, all signals travel through a bus ribbon cable when attached to BioSonics echo-sounders, chart recorders or recording interfaces. A breakout box and ribbon cables are used to connect the ESP to echo-sounders from manufacturers other than BioSonics via the signal conditioning pod.

Digital signal processing may occur on 0 to 10 volt, envelope-detected signals on four input channels. The Analog Devices AD7572 analog to digital converter is used for digital data acquisition. The 12 bit, 25 kHz digitizing process, controlled by a Texas Instruments TMS320C10 digital signal processor (single 40 pin chip), allows an adequate number of samples to define pulse widths down to 0.2 ms.

Software

The user interface software runs on the PC under the regime of Microsoft WINDOWS™ software, a user friendly graphic display that is visually intuitive in its operation. The WINDOWS™ program divides the screen into sections called windows and the user inputs information with a keyboard and mouse (pointing device).

The algorithm package chosen by the operator dictates the processes of the signal processing board.

When the operator runs a selected program on the PC, that program downloads the machine instructions to the board and defines the function of the signal processing. Currently implemented functions include echo-integration and dual-beam processing. Simultaneous use of these two functions is currently being developed, with split-beam processing to be added in the future.

A digital oscilloscope provided on the computer screen can be used for monitoring the incoming data, and for bottom tracking. The potential for an on-screen color echogram is currently being evaluated.

USING THE ESP

The many parameters that need to be accessed for experimental purposes are available in a concise and logically arranged menu system. For ease of operation, the parameters for each experiment can be stored on disk in a configuration file for instant retrieval and selection. This process allows an experiment to be configured in the laboratory. Once in the field, the less skilled operator needs only to modify a few selected parameters like noise thresholds and not be confounded by the others.

The ESP can process multiplexed (i.e., alternate ping) data, allowing simultaneous echo-integration or dual-beam processing of data from two different frequencies. Data can be processed in up to 100 contiguous depth intervals over a total range of 1000 meters. These intervals and the depth-dependent parameters are easily entered in a spreadsheet format. Multipliers in each interval provide the capability of approximating a correction for non-ideal Time-Varied Gain (TVG). Separate noise thresholds can be assigned for each surface-locked interval in the echo-integrator and the dual-beam processor.

Dual-Beam Processor

The main menu headings in the dual-beam processor software are: ***File*, *Setup*, *Graphics*** and ***Run***. The ***File*** menu allows creation, recall or alteration of a configuration file containing preset values for the calibration and processing parameters. A configuration file contains all parameters listed within the ***Setup*** menu, which includes *Process Map*, *Bottom Tracking Parameters*, *Sounding Constants*, *Strata Definition*, *Acoustic Calibrations*, and *Single Target Criteria* menu items. These six menu items contain all of the parameters used to process dual-beam data.

The *Process Map* (Figure 2) is used for informing the ESP as to whether and how the system is set up for bottom tracking and multiplexing. The connection map section enables the processor to correctly apply narrow-beam and wide-beam processing algorithms to the two respective incoming signals. The *Process Map* is also used for naming and controlling the duration of output data files. File naming may be automatic, if desired.

Bottom Tracking Parameters include bottom window size (m), bottom threshold (v), and upper bottom limit (m). The upper bottom limit prevents the processor from mistaking the sync pulse for a close-range bottom return or surface noise.

Sounding Constants (Figure 3) which may be input to the dual-beam processor include the speed of sound (m/s), pulse width (ms), pulse search window (% of pulse width) and wide peak search (% of pulse width). The pulse search window (Figure 4) indicates to the processor how far on either side of the peaks of the narrow- and wide-beam echoes to search for the -6 dB, -12 dB and -18 dB points of the echo (see *Single Target Criteria*, below). The wide peak search (Figure 5) indicates how far on either side of the narrow peak echo the processor is to search for the wide peak echo of the same ping.

Strata Definition includes not only the number and size of strata in which echo signals will be processed, but also separate noise thresholds (v) and range-dependent multipliers for each stratum (Figure 6). The strata can be either surface-locked or bottom-locked. Up to 100 strata with a total depth (range) of 1000 m can be defined. If multiplexing was selected in the *Process Map* menu item, two strata definitions are used for the two respective transducers.

Acoustic Calibration information includes source level measured at various transmit power settings, and receiving sensitivities of both the narrow and wide beams (Figure 7). Echo-sounder transmit power and receiver gain are also provided to the ESP, so that a target strength plot can be accurately computed in real-time. A note edit box allows the user to record messages, such as calibration date, transducer and echo-sounder serial numbers, etc.

Single Target Criteria are used to classify echoes which exceed the noise threshold as either single or multiple targets. Multiple targets are unreliable for target strength information. The dual-beam processor has a variety of single target detection criteria: the pulse widths on both narrow and wide beam channels are measured at the half-, quarter-, and eighth-amplitude points (Figure 8). Targets can be excluded based on any or all of these pulse width measurements.

Graphics offered by the dual-beam processor include a display of target strength by range which is updated in real time as dual beam processing occurs, as well as real-time displays of the input signal on a monitor oscilloscope. The oscilloscope may be used to manually track the bottom return, or the user may select either of two automatic bottom-tracking functions.

The ***Run*** menu simply allows starting or ending of data processing.

Echo-Integrator

The echo-integrator menus are similar to those of the dual-beam processor. Menu items include ***Setup***, ***Map***, ***Strata***, ***Calibrations***, ***Graphics***, ***Bottom*** and ***Run***. The essential differences between the two programs are noted below.

The ***Map*** menu item of the integrator (analogous to *Process Map* in the dual-beam processor) allows connection of only one channel at a time. However, data from alternate pings can be integrated separately using different sets of parameters, if multiplexing is selected.

In the integrator's ***Strata*** menu item, a secondary set of strata can be defined for the same transducer (Figure 10). The single incoming signal can be integrated in two different ways simultaneously using two different sets of strata parameters. Strata can be bottom-locked or surface-locked. If the secondary strata are surface locked, the acoustic signal can be simultaneously integrated with different parameters: options include two noise thresholds using the same strata; or the same threshold but using different strata. The average backscattering cross section may be input for each stratum.

The dialog boxes within the ***Calibrations*** menu item list the hydroacoustic system parameters required for making absolute density estimates. In addition to source level, sounder receiver gain, through-system gain at 1 m, pulse width and speed of sound, the transducer beam pattern factor ($b^2_{av}(\theta)$) is called for.

The ***Graphics*** menu item opens up real-time displays of the input signal on a monitor oscilloscope (Figure 11). If the multiplexing option was selected in the *Map* menu, two displays will be shown, for alternate pings. The integrated signal is displayed as histograms of fish density vs. range (or depth) strata. If the mean backscattering cross section of the fish is known, the real-time density plot is expressed (fish/m^3). If not, the output is reported to the screen in mean v.

Bottom tracking options are similar to those offered by the dual-beam processor. Options are selected within the ***Bottom*** menu item (Figure 12). Bottom window (m), threshold (v), and upper limit (m) are specified, as well as whether the bottom source is internal or external.

Accessing Data Files

Real-time results from signal processing are displayed in user selected and controlled windows on the computer screen. WINDOWS™ also allows improved access to ESP data by sharing it with any other WINDOWS™ program, such as Microsoft's EXCEL™ spreadsheet. The ESP program ESP_VIEW™ is a utility included in the basic ESP software package, which allows the user to look into the binary data files that are produced when hydroacoustic signals are processed by either the echo-integration or dual-beam processing programs. This viewing utility operates in the Microsoft WINDOWS™ regime. Selected portions of binary ESP data output files are translated into ASCII data files for transfer to data analysis programs or commercial database programs. Files may also be edited using ESP_VIEW™.

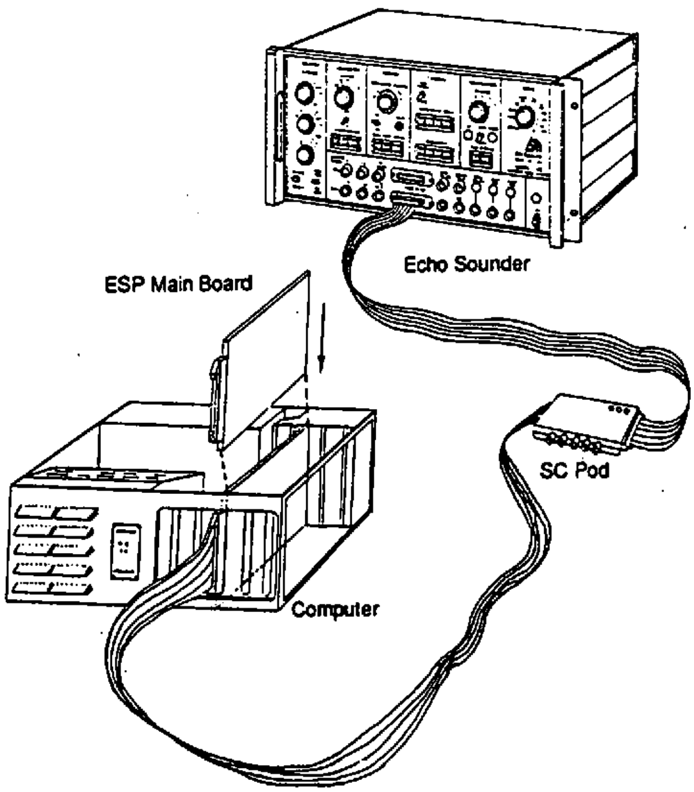

Figure 1. ESP computer and Signal Conditioning (SC) Pod connected to echo-sounder.

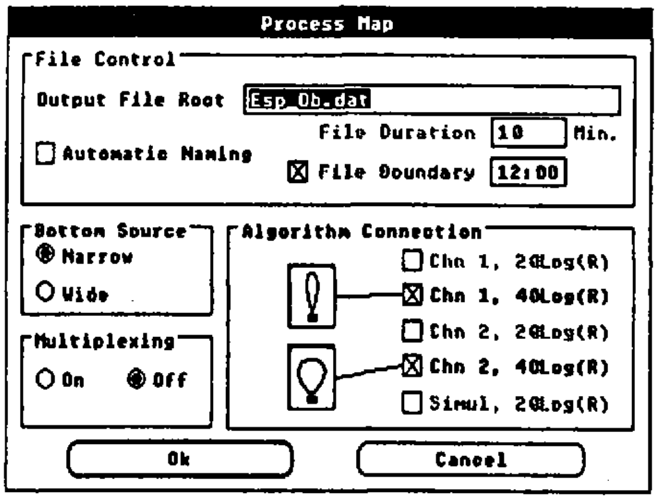

Figure 2. *Process Map* menu item of ESP Dual-Beam Processor, showing File Control, Bottom Source, Multiplexing and Algorithm Connection boxes.

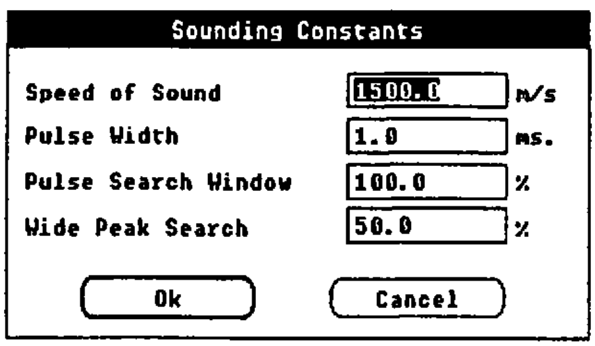

Figure 3. *Sounding Constants* menu item of ESP Dual-Beam Processor, showing dialog boxes for user input of processing parameters.

AN INNOVATIVE ACOUSTIC SIGNAL PROCESSOR FOR FISHERIES SCIENCE

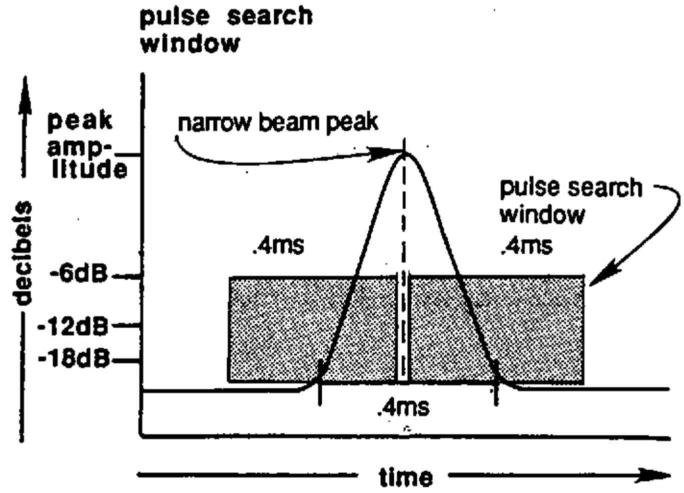

Figure 4. Graphic representation of pulse search window within which the ESP Dual-Beam processor searches for the -6 dB, -12 dB and -18 dB points of the narrow- and wide-beam echoes.

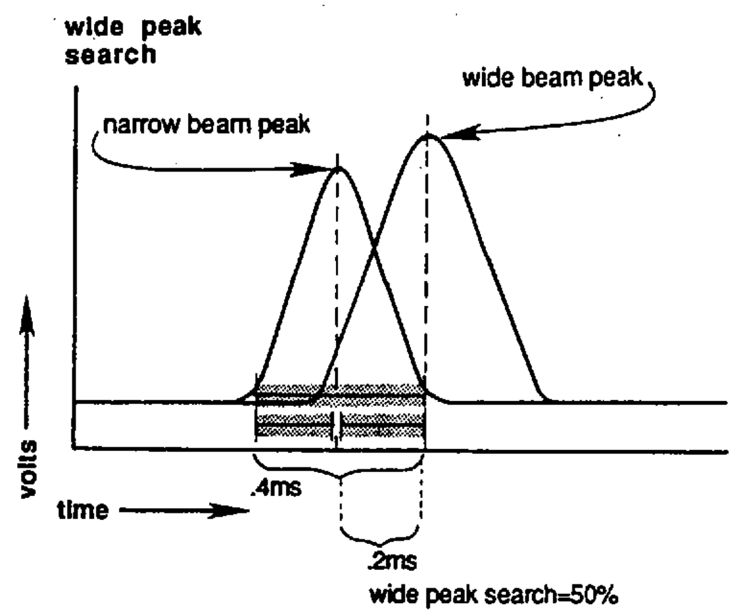

Figure 5. Graphic representation of ESP Dual-Beam Processor's wide peak search, which indicates how far on either side of the narrow peak echo to search for the wide peak echo of the same ping.

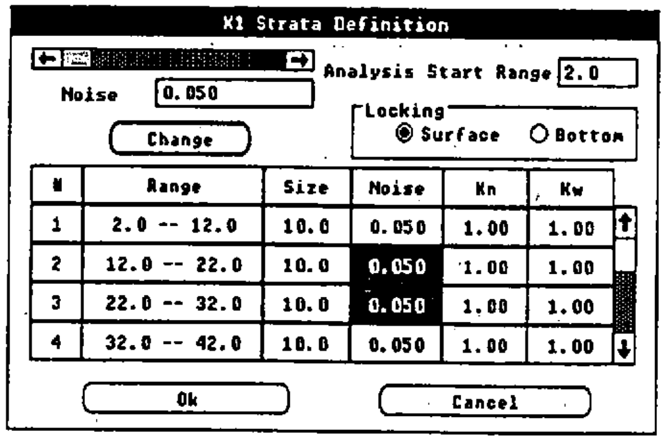

Figure 6. ESP Dual-Beam Processor's *Strata Definition* menu item: up to 100 strata with a total of 1000 m depth (range) can be defined, with separate noise thresholds and range-dependent multipliers for the narrow and wide beams (Kn and Kw, respectively).

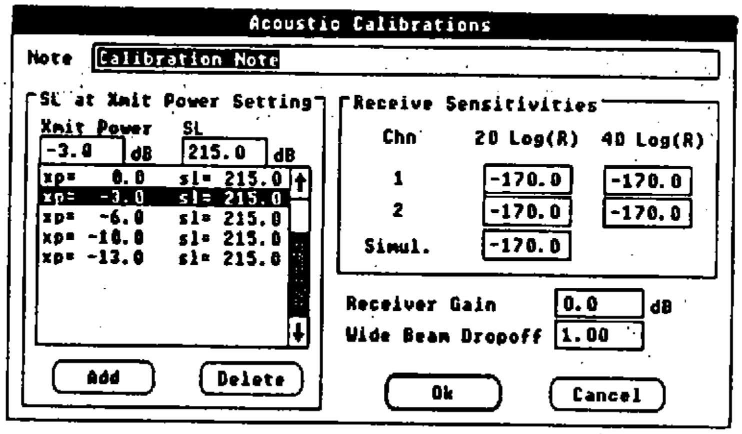

Figure 7. *Acoustic Calibrations* menu item of the ESP Dual-Beam Processor allows input of acoustic system's receiving sensitivities and source level measured at various transmit power settings.

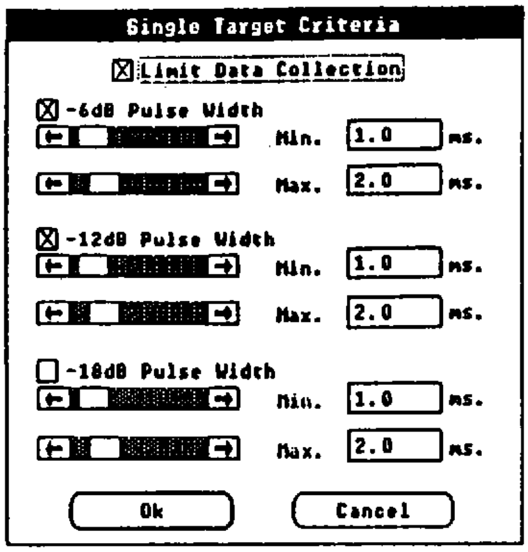

Figure 8. *Single Target Criteria* used by the ESP Dual-Beam Processor to classify echoes which exceed the noise threshold as either single or multiple targets.

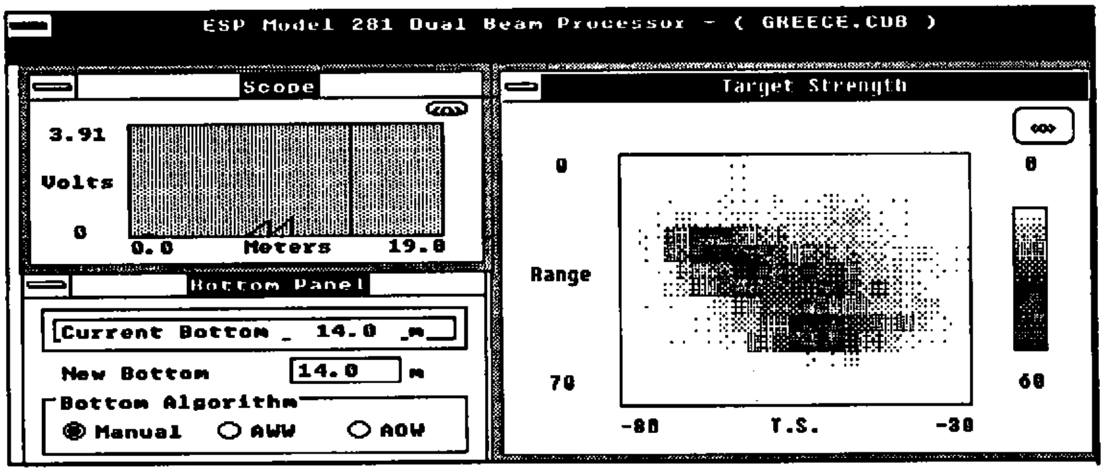

Figure 9. *Graphics* windows of ESP Dual-Beam Processor include real-time, on-screen displays of target strength histogram, bottom panel and oscilloscope.

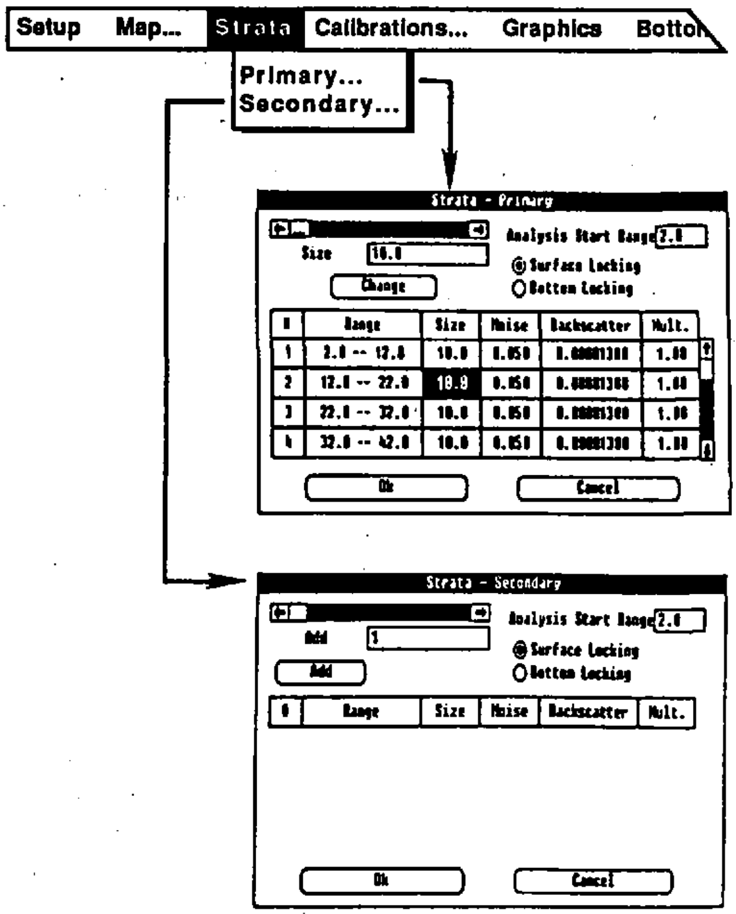

Figure 10. *Strata* menu item of ESP Echo-Integrator showing secondary strata which may be used to integrate the acoustic signal with a second set of parameters. Separate noise thresholds and backscattering cross sections may be applied to each of up to 200 strata.

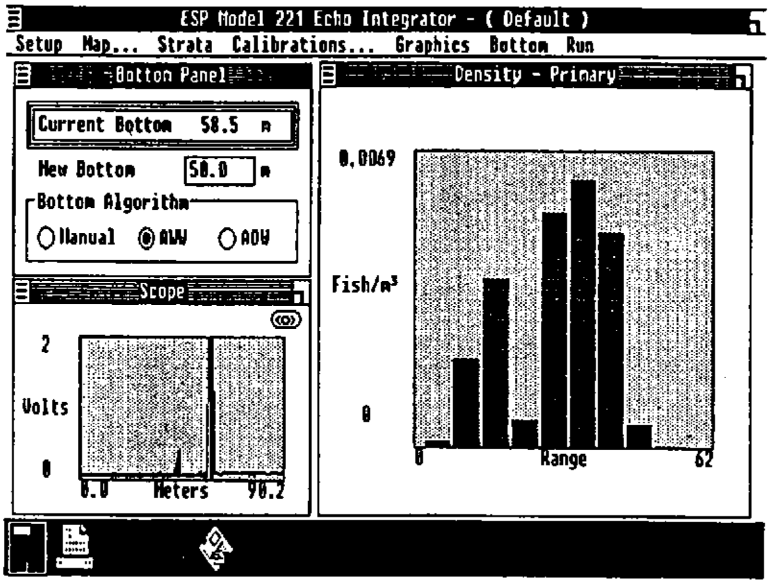

Figure 11. *Graphics* windows of ESP Echo-Integrator include real-time, on-screen displays of fish density histogram, bottom panel and oscilloscope.

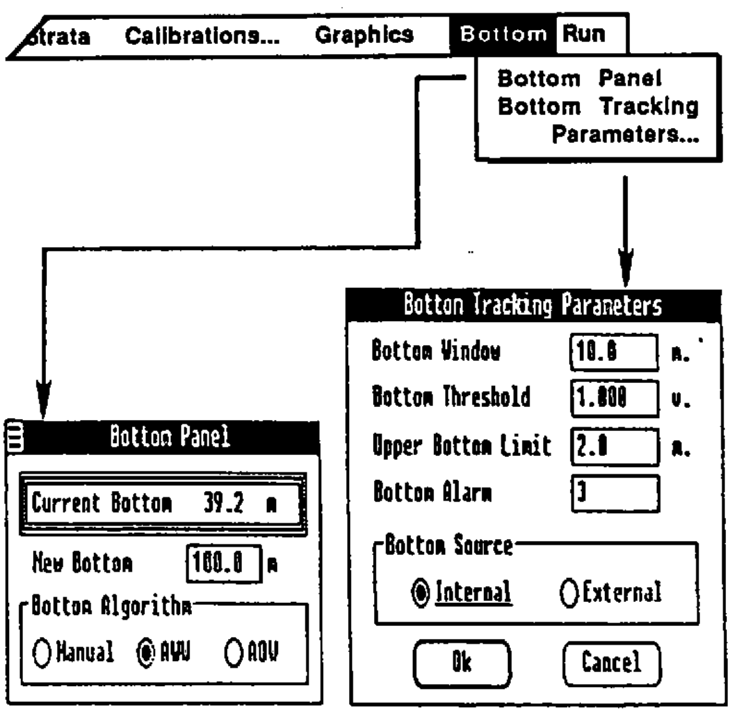

Figure 12. *Bottom* menu item of ESP Echo-Integrator, showing Bottom Panel and Bottom Tracking Parameters boxes.