PROCESSING OF ECHO-SOUNDER SIGNALS FOR REAL-TIME SURVEYING.

R C Chivers (1) and D Burns (2)

(1) Physics Department, University of Surrey, Guildford GU2 5XH
(2) Marine Micro Systems, Kinsale Road, Cork, Ireland

1. INTRODUCTION

Conventional uses of sonar systems in connection with the sea bed tend to be restricted to the ubiquitous measurement of depth with an echo-sounder, or the qualitative rapid mapping of surface topology using a side scan system. There is considerable interest in research laboratories around the world in extracting and exploiting more of the information that is potentially available in the echo trains returned by an acoustically interrogated ocean bottom [1]. Thus, amongst others, Pace [2] has shown the potential of swathe analysis while Orlowski [3] identified the energy content of the second echo as a useful parameter for sea bed identification. The present contribution describes a novel approach to the problem [4] which has been refined as a result of extensive trials [5,6] and is now proving to be of significant value in a wide variety of oceanographic contexts.

2. ACOUSTIC SIGNATURES FROM THE SEA BED

The three primary features of the sea bed that are of interest appear to be its depth, its composition (ie. whether it is mud, sand, gravel, rock etc.), and its roughness. A relatively straightforward discussion of the relation of acoustic parameters to ground types [7] shows that if one uses one of the geophysical gradings of ground types based on particle size bands, a particular type of ground will exhibit a range of values of the acoustical parameter. Use of two parameters will identify a rectangle on a two parameter plot defining the combination of parameters appropriate to a particular type of ground (figure 1).

Based on this, it would be possible, in principle, to define a sonar signal processing system which provided unambiguous identification of the sea bed. The approach could be extended to many acoustical parameters, identifying an appropriate volume in a multidimensional space. The main factors that militate against this are three. Firstly it is rarely the case for particulate ocean beds that only one narrow range of particle sizes corresponding to a single ground type is to be found at any location. Thus any label ascribed will give, at best, the primary component. This is further complicated by varying porosity in sediments. Secondly many of the features of the sea bed are essentially statistical - as can be seen particularly clearly from analyses of ocean bed roughness. Thirdly there are a number of uncontrolled factors that may affect experimental results - ocean inhomogeneities, weather, shoals of fish masking the sea bed, weed on the sea bed, etc..

It is clear then that while it is clearly preferable to base signal processing strategies on clear acoustical models, rather than adopting a purely empirical approach (which can produce an infinitude of unsatisfactory results), the crucial test of a system is its performance under controlled conditions. Complete control in underwater acoustics is, of course, elusive and the only option available is strategic experiments aimed at answering specific questions with respect to the instrumental and acoustic variables involved. By far the most difficult question to resolve is that of 'ground truthing' ie. how do we know what the sea bed is actually like at a given location? If we had a ready means of knowing this we would probably not be devoting so much effort to the development of acoustic methods of determining it! All of the existing techniques (acoustic and non-acoustic) have significant limitations [7] which requires, ideally, a combination of methods to be used if resources permit. Given the cost of oceanic experimentation, computational modelling can play a variety of useful roles in equipment design and development [8].

3. ACOUSTIC BASIS OF THE ROXANN SYSTEM

A more detailed discussion is available elsewhere [6]. The essential principles are that the processing should be performed on non-saturated signals of both the first and second echoes. The initial portion of the first echo contains contributions from both sub-bottom reverberation (at normal or near normal incidence), and oblique surface backscattering from the sea bed. These cannot easily be discriminated and the first part of the echo is thus removed to minimise ambiguity. (It is relevant to say that the analysis which permits the determination of the duration of the segment of the first echo which should be removed is not available in the literature [7], although some steps towards it have been made [9].) The remainder of the first echo is integrated to provide one acoustical parameter, E1.

A second acoustical parameter, E2, is obtained by integrating the whole of the second echo (figure 2). In both cases the integrations are performed after swept gain has been applied. The relevant considerations of the dynamic range available have been discussed in detail elsewhere [10].

4. INSTRUMENTAL IMPLEMENTATION

The variability of commercially available echo-sounder receivers indicated that it would be necessary to develop a parallel receiver for controlled processing of the sea bed signals. The details are given in a previous publication [6]. The most important development has been linking the signal processing system to the ship's navigational aid so that coloured survey charts can be produced in real time on a PC screen in the wheelhouse as the ship is sailing (figure 3).

5. TESTING OF THE SYSTEM

While testing of a system of this type occurs continuously during the development stages, the changes demanded as a result of the tests gradually reduce in magnitude and number. Thus while improvements can always be made, at a certain point it is worthwhile to start collecting test data which can be collated safely, in the knowledge that the system used to obtain it is not changing significantly. To date data from more than 12 extensive sea trials, involving more than ¼ million data points have been collected and are being analysed, in relation to the information from different methods of 'ground truthing'.(ie. side scan sonar (on 5 trials), direct photography, vibrocoring and grab sampling). For example of the quality of the information provided by the Roxann system is shown in figure 4. It appears that it is generally capable of providing more detail than the side scan sonar. For example on one trial a detailed classification of silt types was achieved; on another, the types of clams on the sea bed could be discriminated, while the presence of weed overlying a particular type of sea bed can often be detected.

6. CONCLUSION

It is probable that the data analysis in progress and the subsequent improvements it suggests will enhance the performance of what is clearly already a reliable method of sea bed identification. The 'boxes' on the parameter plots for each sea bed type are close to standardization. If an arbitrary echo sounder is used, a simple two point scaling is needed to calibrate the system, but if a known high quality echo sounder is used, even this simple calibration procedure may not be required.

With the fine tuning expected in the next few months, the system is likely to have a dramatic impact on hydrographic surveying in the nearest future.

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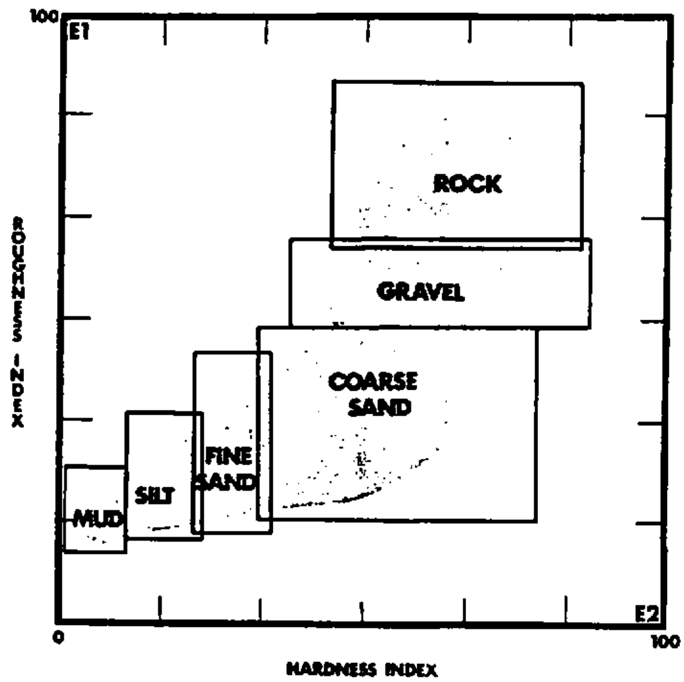

Figure 1 Rectangles defining different ground types on a 2-parameter plot.

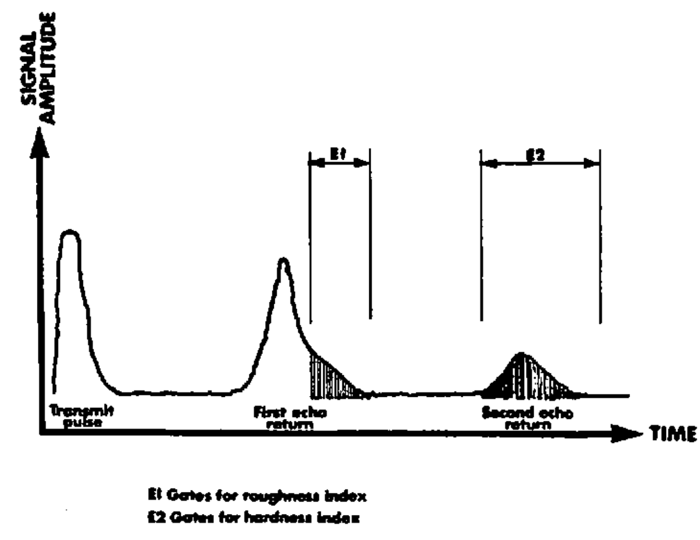

Figure 2 Portions of returning echoes gated and integrated to obtain the acoustical parameters E1 and E2.

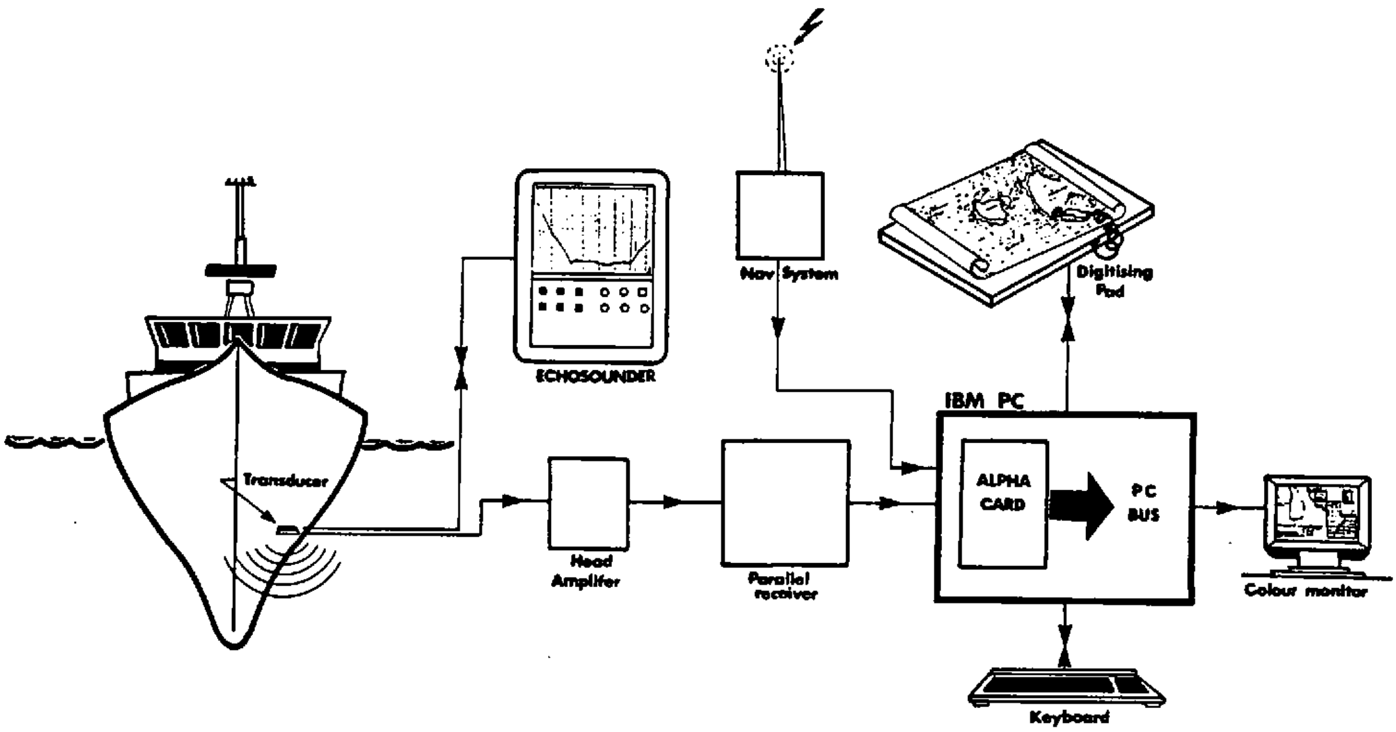

Figure 3 Schematic form of the sea bed discrimination system.

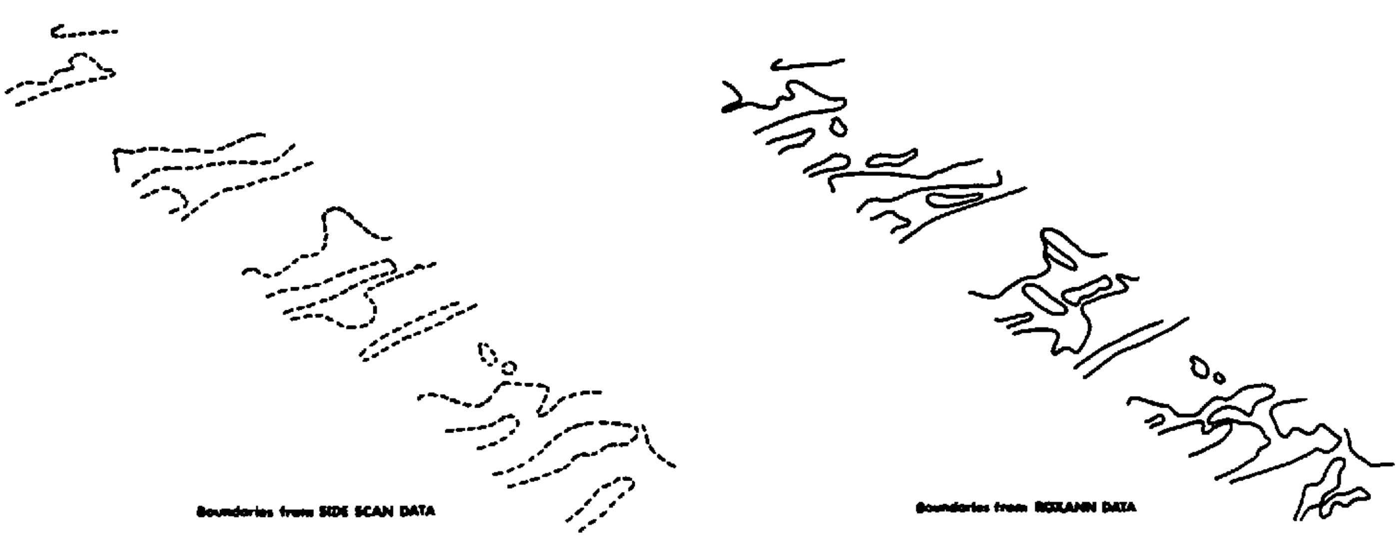

Figure 4 Comparison of boundaries a) from side scan sonar analysis b) from Roxann analysis.