A NOTE ON METHODS OF PRODUCING CORRECTED SIDE SCAN SONAR DISPLAYS

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ABSTRACT

Existing methods of display of side scan sonar information are reviewed. A proposal is made for a new type of display which will enable substantial areas to be surveyed and the results displayed in a form corrected for the major errors introduced by ship motion.

INTRODUCTION

Side scan sonars have been used in a variety of surveying tasks since their introduction in the late 1950's (CHESTERMAN, 1958, TUCKER, 1961). The original means of displaying the signals was by the use of a facsimile paper recorder. Indeed, this still is the conventional method and, by virtue of its simplicity and cheapness, has many advantages.

Other methods have been considered, for example the Cathode Ray Tube (CRT) photographic display developed at Bath (HOPKINS 1970). This display is, however, only a step along a path of development which needs to be pursued much further. The requirements for a more advanced display now appear to be :

(a) Higher positional accuracy

(b) Some automatic means of combining individual sections of corrected record, to form a "mosaic".

The former would be difficult to meet with a CRT display of the type already described, since positional errors would need to be limited to 1 % or less of the maximum range of the sonar. The latter requirement cannot be achieved with any display in current use : it arises naturally from the high data rate of the side scan sonar and from the expanding needs of surveying organisations. (For instance the programmes of Continental Shelf exploration which are being undertaken). An outline is given in this paper of the principles upon which a new display might be based.

THE CONVENTIONAL DISPLAY

The principle of the side scan sonar is well known. The transducer is either attached to the side of the ship or is towed alongside in a free flooding fish. The transducer beam is in the form of a narrow fan pointed sideways, and the scanning of the sea bed is accomplished by the forward motion of the ship (and fish). We shall here refer to " ship position " etc. to imply fish position if a separate fish is being used.

In the conventional display, recording is achieved on a strip of chart paper by either an electrolytic or a spark erosion process (See fig. 1). The stylus moves across the width of the paper, starting at one edge at the instant of sonar transmission, and completes a sweep in the time taken for the sound to be scattered back from targets at maximum range. As the ship steams, the paper is slowly advanced in a longitudinal direction.

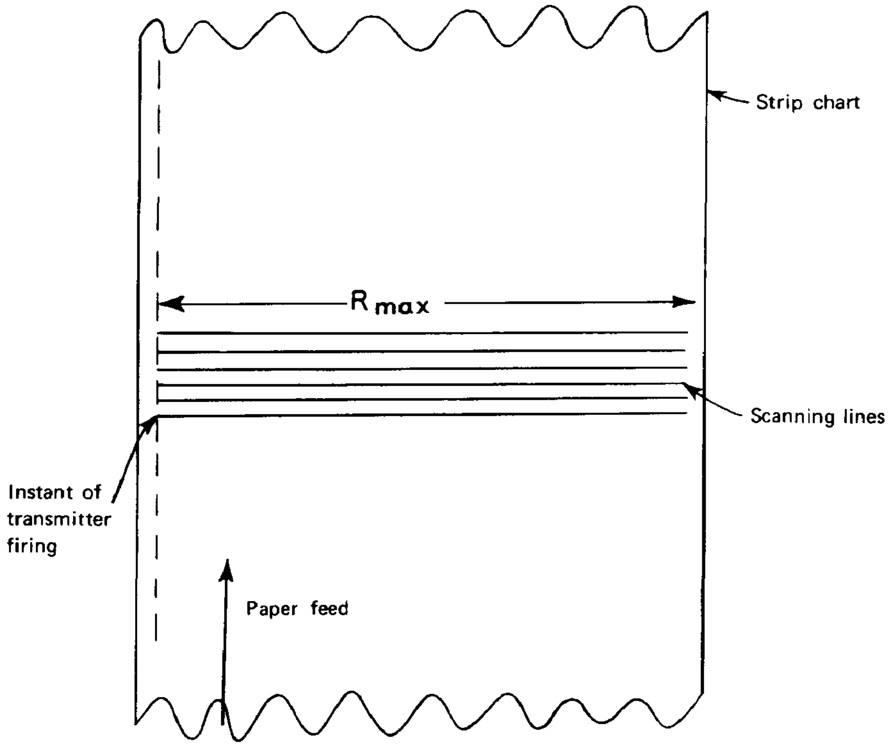

FIG. 1. — Conventional paper chart.

If the ship carrying the sonar follows a perfectly straight course along heading (i.e. with zero drift) and at a constant speed of the correct value, the resulting paper record can be thought of as a map of the sea bed. Strictly, this also requires that the depth of water under the transducer be small compared with the range of the sonar, otherwise a non uniform motion of the stylus is required. In this way the slant range measured by the sonar, can be converted into plan range on the display.

It is usual for a single electric motor to drive the stylus and paper feed arrangements, and for fixed gearing to be employed between the two. Thus, more often than not, the scales along and across track are unequal because the paper is not being advanced at a rate commensurate with the actual ship speed. If one notes that in addition

(a) the ship will often drift relative to heading,
(b) the track is not usually a straight line for any appreciable distance, and
(c) the depth below the transducer may vary appreciably,

it will be clear that the conventional display must yield a record which is often grossly distorted in the geometric sense.

THE CRT DISPLAY

The CRT display has been described elsewhere, so only the basic principles will be reiterated here. The cathode ray tube is scanned to produce a short section of record, the operation taking a time in the order of several minutes. A 35 mm camera equipped with negative film views the tube for the period of scan, after which the shutter is closed, the film wound to the next frame and the scanning of the next section is commenced.

The pattern of scanning lines is shown in fig. 2. Allowance is made for the varying value of ship speed by adjusting the vertical timebase : this varies the line spacing δ. Correction for the drift of the ship relative to heading is achieved by rotating the scanning lines through the angle θ.

Although it has not yet been attempted, it would be possible to correct for the difference between slant and plan range by appropriate scanning of the CRT. If the time elapsed between transmission and the reception of the scattered sound is t, the plan range is simply :

$$r = \sqrt{\frac{c^2 t^2}{4} - d^2}$$

where d is the depth of water under the transducer and c is the sound velocity. A fast timebase obeying this law could be constructed using analogue computing principles or, more accurately, by using a digital system.

We have used this method of display for several years (CHESTERMAN and HOPKINS 1971); our method is to log ship's position and heading at sea every six minutes and to tape record the sonar signal. The tape recording is subsequently replayed into the display with appropriate magnitudes of δ, θ calculated from the logged information. After a short section has been displayed, new values of the parameters have to be adopted. These are set up manually on the display controls. The final output (after photographic processing) is a large number of small sections of film (or of photographic prints, if preferred) which must be assembled to give the mosaic. At present this is done by an operator and this, together with the manual setting up referred to, constitutes a major limitation of the system.

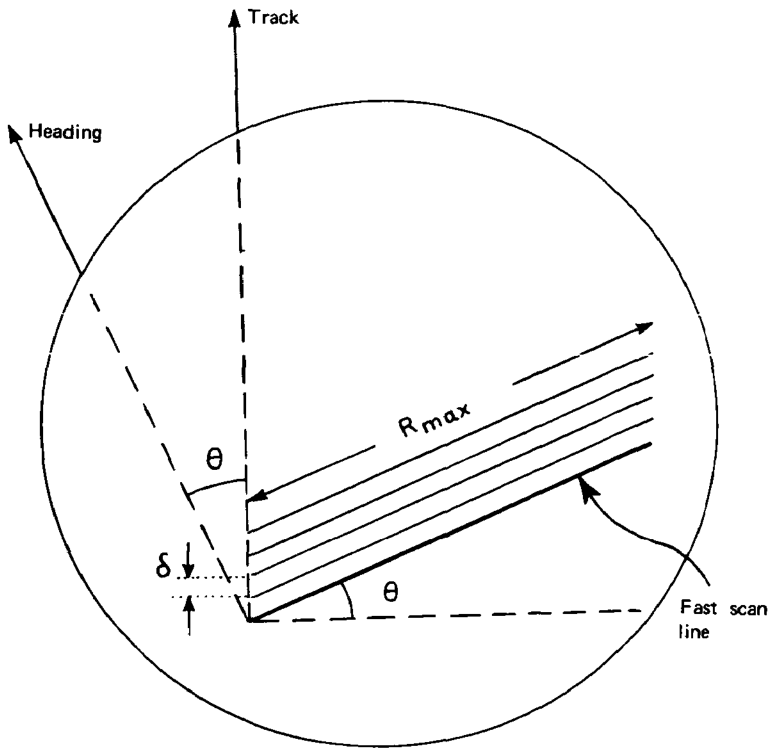

FIG. 2. — CRT display, with corrections.

THE PRINCIPLES OF AN AUTOMATIC DISPLAY

The CRT display, as used at present, can only be corrected at intervals of a few minutes. Moreover one assumes that the section of track within the limits of the display is straight. Our experience has shown that this is not always the case, and that accurate correction of the display cannot be achieved because the logging process proceeds too slowly. Clearly some automatic logging system is required, which will record position coordinates and heading at much shorter intervals, say 1-10 sec. The ultimate appears to be to fix ship's position and heading at each transmitter firing. If there are significant variations in heading (and therefore beam direction) in the interpulse period, severe signal loss will occur and the transducer beam itself needs to be stabilised against yaw. We need not, therefore, consider a higher logging rate.

If one assumes that this position and heading information is available, then the form of the display is now conceived as a plotting of position in geographical coordinates, at each transmitter firing, followed by a fast

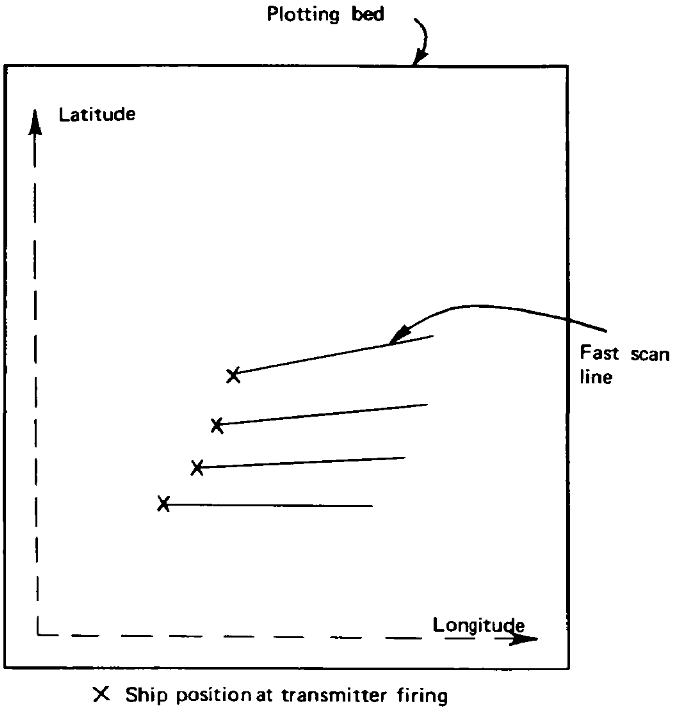

FIG. 3. — Automatic display in geographic coordinates.

scanning line pointing in the beam direction (see fig. 3). This form of display ought to be capable of complete correction for the two-dimensional motion of the ship relative to the earth's surface. In addition, the requirement for slant to plan range conversion could be incorporated by logging depth. It is envisaged that the display would be fed with a tape recording of the sonar signal, together with the digitally recorded position, heading, and depth data. This would, of course, be done as a post-survey operation. One would probably require the display to handle the results of several hours of surveying.

THE FORM OF THE EQUIPMENT

At present, the form of the equipment can only be speculative. For high accuracy of mosaicing, a mechanical plotter of the type already in use for automatic cartography seems to be an obvious choice. One would have to add to it some special means of plotting (in intensity modulated form) a single line of sonar information. This would need to be done fairly rapidly and the choice might lie between a flying spot optical system or an electronically scanned system recording on prepared chart paper and using an electric current. The latter alternative would have the obvious advantage of being immediately visible. The start of each line and the direction of the lines (fig. 3) would be set up using the logged data, the control of the plotting table being by means of a small digital computer.

To operate the display in real time might be difficult and possibly rather unnecessary. Provided that the process is slowed down by a factor of not greater than 10, the time required for display may not be prohibitive. Some estimates of the requirements of the system have been made using the Bath sonar as an example.

SUMMARY OF REQUIREMENTS OF THE SYSTEM

1. Sonar

The Kelvin-Hughes sonar used has the following relevant parameters :

Maximum range : 750 m;

Pulse repetition rate : 1 Hz;

Pulse width : 1 ms, corresponding to 75 cm resolution;

Beamwidths : Vertical : 7.5° (— 3 dB);
Horizontal : 1.8° (— 3 dB).

From the latter we deduce that the accuracy of position plotting, across beam, at maximum range, is

$$750 \text{ m} \times 1.8 \times \frac{\pi}{180} \approx 24 \text{ m}$$

2. Ship Logging System

	Parameter	*Accuracy*
(a)	Time/Serial Number	For identification only.
(b)	Depth	± 1 m.
(c)	Fix coordinates	± 10 m, see sonar across-beam accuracy.
(d)	Heading	± 0.5°, see sonar horizontal beamwidth.

A good position fixing system is essential.

3. Plotter System

Consider an area to be surveyed of 5 km × 5 km. We assume that it will be displayed at a scale of 1/5 000; this will mean that the bed of the plotter will measure 1 m × 1 m. The maximum range of the sonar, as seen on this display, i.e. the line length, will be 15 cm.

If we assume that the survey is conducted at a speed of about 2.5 m/s (5 knots), then the line spacing, δ, will be approximately 0.5 mm on the display corresponding to 2.5 m on the sea bed. (This should also be compared with the sonar accuracy). Clearly, the line printing mechanism will need to have a limiting resolution rather better than this.

The positioning accuracy of the plotter will need to correspond to $\pm$ 2 m in 5 km, i.e., 1 in 2 500, which is an error of 0.4 mm on the display.

If some overlap were allowed between sonar runs, then a 500 m wide path might be surveyed at each traverse. The 5 km square would thus take about

$$\frac{10 \times 5000}{2.5} \text{ sec} \approx 3 \text{ hours to survey.}$$

Allowing for a ten-fold time expansion on replay, we should be printing one line of sonar data every 10 sec and the whole survey would take about 30 hours to display in corrected form.

CONCLUSIONS

A tentative proposal for an automatic method of producing accurate side scan sonar maps has been outlined. A number of problems will need to be solved before this can become a reality.

(a) The means of line printing sonar data on a cartographic plotter needs to be devised.

(b) Appropriate sensors will have to be provided on board the survey ship, together with a digital logger, to enable the various parameters concerned with ship motion to be recorded.

(c) Some consideration must be given to the treatment of errors of fix position and the like, so as to secure a " best fit " between adjacent sections of the final mosaic.

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