PRACTICAL EXPERIENCE WITH HI-FIX

by Lieutenant Commander E.M. BRADLEY, R.N. (Retd.)

IHB Note. — By kind permission of the author and the Royal Institution of Chartered Surveyors we are here reprinting large extracts from an article which first appeared in the February 1970 number of the periodical *Chartered Surveyor*.

The article covers a five-year period during which hydrographic surveys with Hi-Fix equipment were carried out in the Antarctic, the Canadian Arctic, and in the North Sea. The author describes the difficulties encountered in each case and how each was surmounted, the object in view being to use Hi-Fix surveys for the establishment of charts that would meet the requirements of present day navigation.

As with any other radiopositioning system, with Hi-Fix it is essential, if accurate and reliable results are to be obtained, to carry out a series of calibrations, to make a study of the errors, and to take numberless precautions. And for this practical experience is irreplaceable.

Although the surveys in the South Orkneys and in the Canadian Arctic have already been treated in detail in Volumes 6 and 7 of the Supplement to the *International Hydrographic Review* we are nevertheless retaining certain passages in the present article referring to these particular surveys in order that the reader may have an overall picture of all the practical measures, and thus be able to obtain the maximum benefit from this radio aid.

IN THE ANTARCTIC

In the summer season 1964-1965 the writer was in charge of the Royal Navy Antarctic Survey Party engaged in hydrographic surveys off the Antarctic Peninsula and the off-lying islands. The cooperation of the British Antarctic Survey was obtained and their vessel RRS *John Biscoe* (Captain T. WOODFIELD) was equipped with Hi-Fix.

The Hydrographer of the Navy required as much information as possible about the operating characteristics of Hi-Fix both in general terms and in the special conditions prevailing in the Antarctic. At the same time the usual pressure to bring back as much new surveying work as possible was present. The decision to work in the two-range mode was in the circumstances an obvious one. Only the *John Biscoe* was equipped for the work and so there could be no question of making use of other surveying units even if the hyperbolic mode had been selected. The sites for the Hi-Fix stations ashore could be chosen only after a proper reconnaissance of the area and so all the computational work associated with coordinating them and calculating the lattice had to be done on the survey ground. The two-range lattice is, of course, much easier to prepare and draw than the hyperbolic lattice, so this factor also weighed in the choice. And finally, with no helicopter to call on, the task of looking after two shore stations would be less onerous than looking after three.

Calibrations were carried out :

1. to determine the "electrical centre" of the installation in RRS *John Biscoe;*

2. to determine the locking constant of each slave station as it was established; and

3. to test the value of the phase lag factor employed.

Hydrodist, an adaptation of the Tellurometer equipment for hydrographic surveying use, was used in all the calibrations. The master Hydrodist equipment was set up on the bridge of the *John Biscoe* and the remote Hydrodist equipment was set up at the slave station close to the Hi-Fix mast. When calibrating the electrical centre the ship manœuvred in a tight circle staying in the same geographical position as far as possible. Hydrodist readings and Hi-Fix readings, both converted to metres, were compared with the slave station bearing ahead, astern, on each bow, on each beam and on each quarter. A graphical plot of the results is shown in figure 1. It can be seen that to all intents and purposes the electrical centre coincided with the Hi-Fix mast.

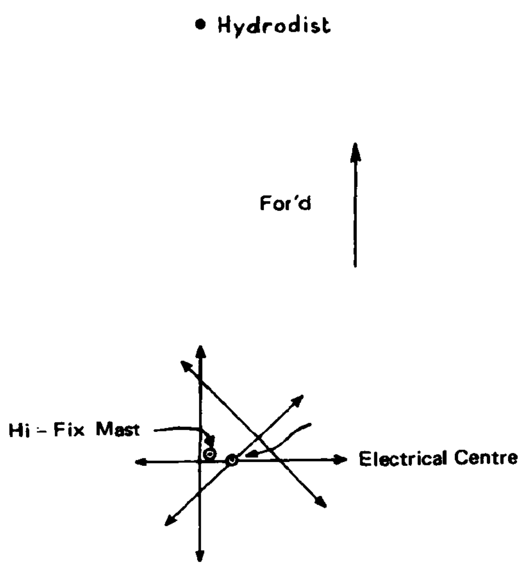

FIG. 1. — Plot of the electrical centre of RRS *John Biscoe*, 16 January 1965. (Scale : 1 inch equals 36 metres).

The locking constant of a slave is the difference between the actual pattern read off the counter and the theoretically correct pattern by computation. The difference exists because of the effect of the induction field on the radiated field at both master and slave stations and because of the effect of the overland path at the slave station. By convention it is always less than one lane and it is always subtractive from the counter reading.

Calibration was by moving in the ship around a slave station at constant distance and covering the whole arc over which the slave station was to be used for surveying. A range of 10 km was used in the *John Biscoe,* although distances as short as 3 km (or even 1.5 km according to some authorities) are said to be satisfactory. After correcting readings to the ship's electrical centre, locking constants were derived. These were plotted against bearing of the slave station to see if any relationship could be established. In all the five calibrations carried out in the Antarctic only a random scatter of up to 0.05 lane either side of the mean was apparent. Arithmetical mean values were therefore accepted and these values applied at the slave stations to make the radiated patterns agree as closely as possible with the computed patterns.

The Admiralty Manual of Hydrographic Surveying recommends the use of a standard velocity of propagation of 299 776 km/sec. Variations from this, whether due to induction field effects or to the conductivity of a sea water or a land path, are regarded as phase lag effect and are allowed for by the application of different phase lag factors. With other radio position-fixing systems, where the master and slave stations transmit on different frequencies, there is virtually no other way of proceeding. With Hi-Fix, however, most users prefer to work directly in differing velocities of propagation, although the writer himself continues to prefer the Admiralty Manual method and has always used it.

In the Antarctic a phase lag factor of 0.999 867 (equivalent to a velocity of propagation of 299 736 km/sec) was used. An attempt was made to check this value by calibrating against Hydrodist while steaming directly towards a slave station. The observations spanned a range of only 17 km. Of 21 observations, 17 plotted within 2.5 metres of a mean line whose slope indicated a phase lag factor of 0.999364 (velocity of propagation 299 585 km/sec). Beyond indicating that the phase lag factor used was almost certainly too high, this result is not considered significant. As the surveys were at relatively short range it did in fact confirm that no plottable error was likely through this cause on the survey scale of 1/50 000.

IN THE SOUTH ORKNEYS

During the Antarctic summer two major surveys were undertaken using Hi-Fix. An account of the South Orkney Islands survey has been published [3]. In all 2 400 miles of soundings was run and an area of 570 square miles sounded out. It is estimated that without Hi-Fix only a quarter of this would have been achieved. In 800 hours of use the equipment was off the air through defect for less than 12 hours.

Much useful Antarctic experience was gained. The importance of carefully selecting the sites for the slave stations was underlined. On one site, equipment was damaged several times by katabatic winds sweeping down a nearby glacier — a factor which had not been considered in choosing the site. One of the most difficult problems proved to be finding adequate means of anchoring the Hi-Fix mast. Stakes hammered laboriously into frozen shale pulled out easily when the permafrost retreated. Forty-gallon drums of stones and cement buried deeply in snow proved barely adequate a fortnight later when rain had washed the snow away and left them perched precariously on ice. The use of gabions is recommended together with specially constructed sleds to be covered with boulders or with stones in sandbags. The splendid qualities of the two-man Arctic tent were demonstrated. It was used to house men and equipment and it is doubtful if anything more sophisticated would serve as well. The diesel-driven battery chargers ran successfully in the open air.

The only serious trouble encountered in the Antarctic was with the lane identification system. This failed to indicate whole lane number reliably. Often the indication was 1.5 lanes too high or too low and sometimes the discrepancy exceeded two lanes. In the South Orkney Islands survey frequent visual checks were possible and these soon demonstrated that the HF pattern counters maintained the whole lane number perfectly correctly. Loss of lane integration is called "lane slip" and this can occur when signal strength is weak or when noise occurs on the frequency or when a relay in one of the units malfunctions. In fact lane slip occurred only twice and it was detected and corrected on both occasions.

The trouble therefore lay with the lane identification system. If the principles on which it operates are recalled it will be appreciated that for an unambiguous reading (i.e. one differing from the correct HF pattern reading by less than 0.5 lane) the HF and LF patterns must not deviate from their locking constant calibration values by more than a combined total of 0.04 lane. Obviously pattern stability of this order was not being achieved. At the time this was attributed to reradiation of the pattern from the steep coastline and from icebergs, and also possibly to changeable phase lag effects when floating ice interposed on the wave path. As the survey was on a scale of 1/50 000, pattern instability of 0.20 lane (such as might cause a two-lane misidentification were the error all in the HF pattern) would misplace a sounding only very slightly.

IN THE CANADIAN ARCTIC

Superficially it might be expected that there would be little difference between operations in the Arctic and the Antarctic. In fact the opposite is the case, as is made clear by the extremely interesting papers by R.M. EATON [4]. The comparative accessibility of the Canadian Arctic means that quite large expeditions can be mounted economically, that continuous support can be given to the field parties from their head office and that preliminary work can begin before the sea ice breaks up.

The Canadians have favoured the hyperbolic mode so that their Hi-Fix chains could be used by more than one surveying vessel. The extra work involved in preparing the hyperbolic lattice represented no loss in the time spent sounding, as it was feasible to keep the preparatory work well ahead of the boat-work. Latterly an ingenious method of graphically preparing a rough hyperbolic lattice (assuming a flat earth) has been brought into use. This suffices for plotting in the field, but before any accurate inking in of the soundings is done all fixes are sent back to Ottawa for computer conversion to a Universal Transverse Mercator plot. The fact that this plot is back in the Arctic within two weeks emphasises the difference in the quality of support feasible between an Arctic and an Antarctic project.

A monitor station is recommended when Hi-Fix is used in the hyperbolic mode. It consists principally of a static receiver, possibly augmented by automatic recorders, installed to monitor the readings of both patterns. Ideally the monitor should be in or near the sounding area with a wave path typical of that experienced by the surveying vessels. This is so that changes in pattern reading can be confidently regarded as actual pattern fluctuations and not merely the result of changes in local ground conductivity.

Erecting Hi-Fix stations while the fast ice was still in position yielded some interesting results. A master-slave baseline lane count gave 562.52 lanes in unbroken heavy ice, 561.70 lanes in two-tenths broken ice and 561.58 in no ice. These are equivalent to velocities of propagation of 299 230, 299 670 and 299 730 km/sec respectively. A velocity of propagation obtained elsewhere over fast ice with polynias (pools of water) of 299 550 km/sec should be contrasted with the first of the above figures.

Errors caused by using an incorrect phase lag factor (incorrect velocity of propagation) are not as significant as when working in the two-range mode. Provided there is no land path to be considered the error should be nil on the straight line "hyperbola" which bisects the master-slave baseline. For this reason the Admiralty Manual of Hydrographic Surveying recommends that the pattern should be computed and set symmetrically about the baseline bisector. The common practice, however, is to try to zero the pattern on the master transmitter. If this method is employed pattern calibration will reveal a zeroing error (the misclosure of zero on the master) and a phase lag (or velocity) error which will increase with hyperbolic lane number. The Canadians allow for both these errors in their computer.

For the pattern calibration the Canadians recommend a very strict procedure. A Hi-Fix fitted launch is preferred to a larger surveying vessel to avoid the possibility of reradiation from other masts and aerials. The launch, which should be moored, is intersected by three theodolite observers at the same time as Hi-Fix readings are taken in the launch and at the monitor station. Ten observations are taken at each station. Stations are situated at low, medium and high lane numbers, preferably where the lanes are widely spaced, and never within 5 km of a transmitting station. As a result of such a calibration the settings at the slave station could be altered to adjust the zeroing error (or to obtain close agreement with computed hyperbolae in the survey area if preferred). Any phase lag error revealed could be applied only as a fixed error.

Fixed errors should be obtained all over the survey area after the pattern calibration and any subsequent pattern adjustment has been made. Apart from the phase lag error already referred to, land path errors are revealed by these observations. In the survey of South Hell Gate the fixed error in one pattern changed from −0.08 lane to −0.44 lane over a distance of 1.5 km as land and a 200-m high cliff intruded on the wave path. Fixed errors can only be applied mentally to the counter readings.

It has generally been accepted that the ship's electrical centre should coincide with the Hi-Fix receiving aerial when operating in the hyperbolic mode. The Canadians cast doubt on this after carrying out a swing in their ship, the *Kapuskasing*.

Until 1966 the Canadians had not used the lane identification system. Consequently their assessment of pattern stability and other random errors was based on monitor readings on the one hand and a general synthesis of probable errors on the other. The monitor showed a tendency of the pattern to drift by up to 0.02 lane over a three-week survey period. The daily maximum divergence from the mean value would be 0.04 lane typically, with a maximum divergence for the whole period of 0.06 lane. In synthesising the errors of a ship-borne receiver EATON concluded that the 95 per cent probability error would be less than ± 0.10 lane and the maximum likely error ± 0.12 lane.

THE 1966 HI-FIX TRIAL

In 1966 the Hydrographer of the Navy ordered H.M.S. *Myrmidon*, a coastal surveying vessel, to carry out a Hi-Fix trial in the North Sea. Throughout the trial the master equipment remained in the ship and so the tests were designed for a vessel operating in the two-range mode.

The most important test was designed to investigate phase lag (and therefore velocity of propagation) over a sea water path. A slave station was erected in an extremely favourable position only a few yards from the high water line on Landguard Point near Felixstowe. The ship then proceeded to calibrate the Hi-Fix in steps from a position 1.5 km from the slave to a point off Calais 113 km away. From each calibration point there was a direct sea water path to the slave, and, to avoid the possibility of even a drying Thames estuary sandbank interposing, observations were taken near to high water. The results are shown in figure 2. Two straight lines were drawn — one for the HF pattern and one for the LF pattern. No curve would seem to fit the points better. Although there is some scatter in the observations within 5 km of the slave station, the straight line still seems to hold good right down to the point of origin of the graph. The actual propagation velocities yielded were 299 636 km/sec for the HF pattern and 299 667 km/sec for the LF pattern. Theory would have it that the HF should be less influenced by phase lag than the LF pattern, and perhaps it would be better to regard the mean value of 299 650 km/sec as a reasonable approximation, with random errors of the order of ± 17 km/sec noted as having been observed on this occasion. The weight of evidence of this and other observations by now indicates that a value of 299 660 km/sec might possibly be even better.

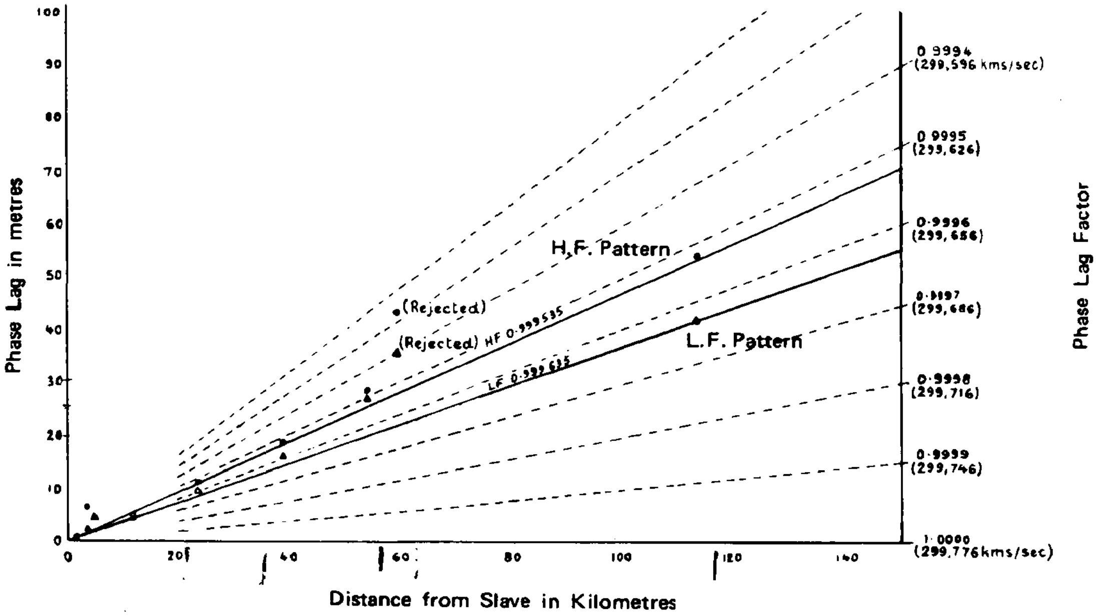

FIG. 2. — Hi-Fix velocity of propagation and phase lag over a sea water path, North Sea, April-May 1966.

The next test was to explore the effect of a land path. No hydrographic surveyor aware of the large variations in conductivity possible over a stretch of land would accept more land path than he need. On the other hand the lack of a suitable site for a Hi-Fix station might force him to consider sites a little inland, and the question in his mind would then be how far inland he could safely go. The test consisted of siting one slave station just 50 m in from the high-water line and a second slave station in the same direct line from the ship first 0.33 km, then 1.24 km and finally 2.18 km beyond the first. The ship was lying 8.5 km off-shore and was fixed by theodolite and Tellurometer readings at the same time as readings were taken of both sets of Hi-Fix counters. The Hi-Fix reading (converted to metres) of each slave was compared with the appropriate spheroidal distance and a figure which amounted to locking constant, phase lag and distance to electrical centre at the ship was obtained for each slave. As the slaves were in line the difference between the figure obtained for the inland slave and the figure obtained for the slave on the high-water line should have been attributable to the phase lag of the land path between them. The results were as shown in figure 3. Phase lag can be seen to be building up at about 2 km, but certainly from these results there would seem to be no major objection to siting a slave as much as 1 km inland. Of course, if this were done, it would still be prudent to ensure that the amount of land path was constant through the whole arc over which the slave station was going to be used.

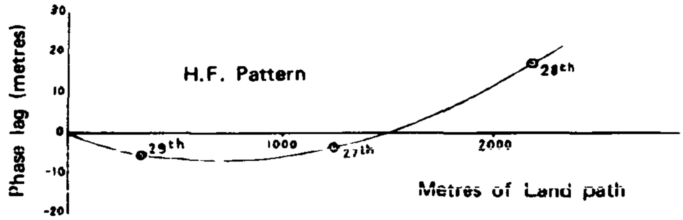

FIG. 3. — Hi-Fix stability trials at Lowestoft, 15-16 August 1966.

A further experiment was to explore the effect of a drying bank in the wave path. The ship anchored off Shoeburyness in a place where at high water there was 8.5 km of sea and at low water 2.5 km of sea and 6 km of drying sand and mud in the wave path to the slave. Comparison between spheroidal distances to the slave (obtained by theodolite and Tellurometer) and equivalent Hi-Fix distances revealed no consistent change in phase lag with the rise and fall of the tide. The reason for this surprisingly favourable result can only be that the tidal cycle does not allow time for the banks to dry out properly, and that so long as they are damp they have a conductivity similar to sea water.

Observations were taken on several days aboards HMS *Myrmidon*, plotting mean daily value of observed minus calculated Hi-Fix reading against appropriate tidal range. The result is shown in figure 4. The reduction in tidal range, of course, left more of the foreshore permanently uncovered and the increase in phase lag indicated in the figure could be the result of this. The inference from this test is therefore that a drying bank in the wave path should be avoided not because of the semi-diurnal rise and fall of the tide but because of the difference between the spring and neap ranges.

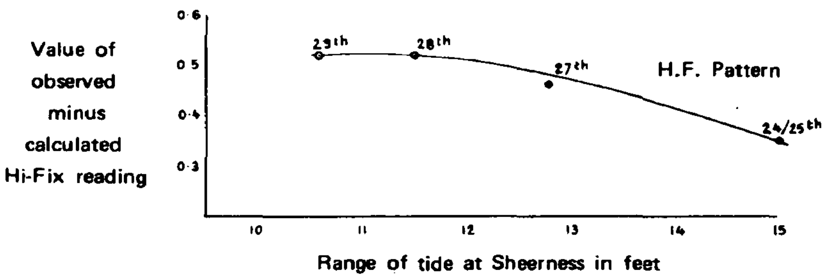

FIG. 4. — Drying bank effects — phase lag against tidal range — Shoeburyness, April 1966.

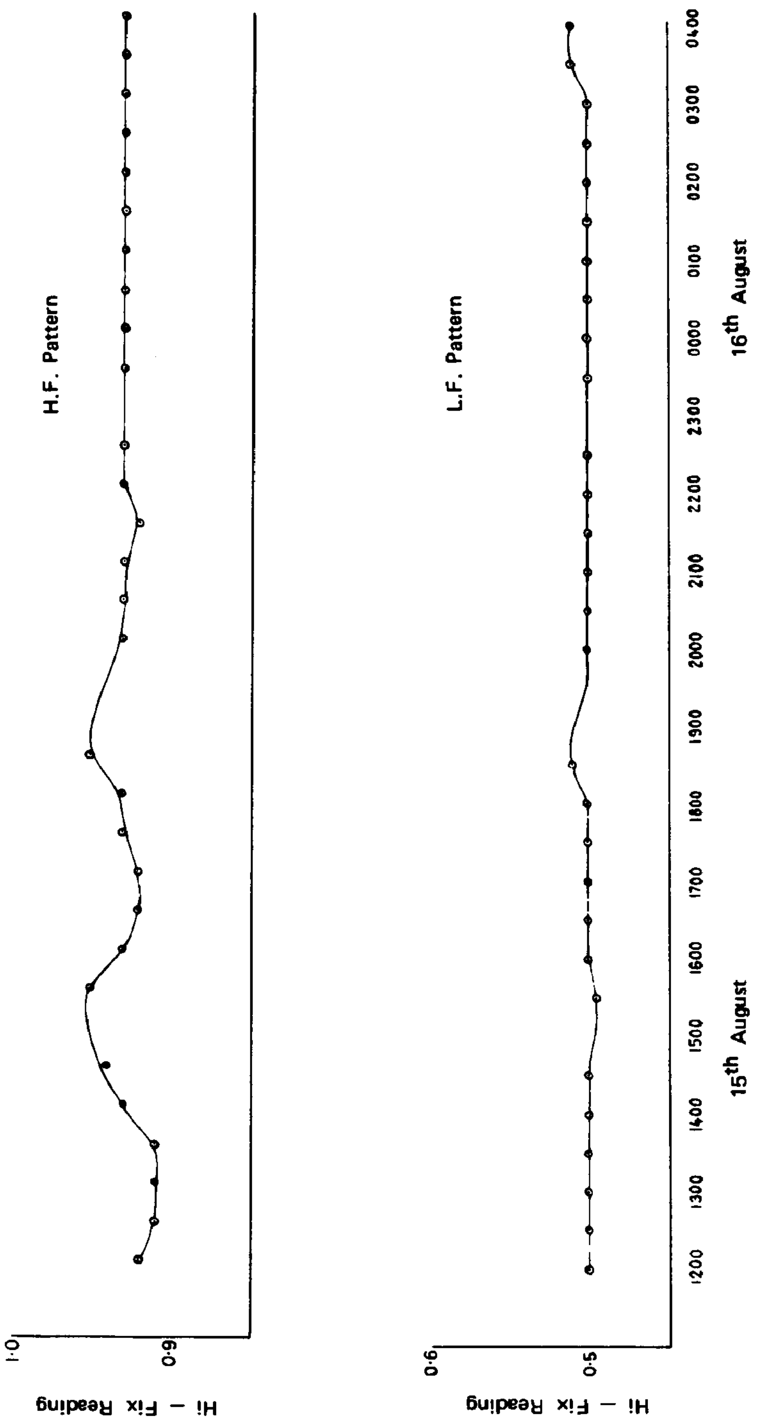

FIG. 5. — Hi-Fix stability trials at Lowestoft, 15-16 August 1966.

When Hi-Fix is operated in the two-range mode the only way to monitor pattern stability is to immobilise the master. In the Hi-Fix trial the *Myrmidon* was berthed alongside only 2 km from the slave. A short distance was chosen to minimise the effect of changes in phase lag and rule out all possibility of sky-wave interference. The results were as shown in figure 5. No reason can be given for the 0.04 lane amplitude oscillation in the HF pattern, nor for why it should suddenly have ceased at 8 p.m. With a stationary vessel the relative bearing of the slave station remains constant, and so any variable reradiation effects from the ship's superstructure are not taken into the reckoning. Worse rather than better pattern stability might therefore be expected for a ship at sea.

It is well known that thundery conditions and possibly even just heavy rain may render Hi-Fix unusable. Heavy interference from an outside radio source can also make a receiver lose lock. Tests were made with the ship's own transmitter. It was found that the transmissions had to be within 12 kHz of the Hi-Fix frequency before the reading was affected, and then only when the carrier frequency was switched on or off. With the ship's sets switched off, tuning the aerials to the exact Hi-Fix frequency did not disturb the Hi-Fix pattern.

The practice of calibrating the pattern by setting up a Tellurometer or Hydrodist set alongside the slave station's transmitting mast had been called in question. For a test a man walked about within the aerial array. The APC counters at the slave station moved by 0.06 lane, but the pattern reading on board was unaffected. In the ship a man carried a metal ladder about within the aerial array as though engaged on a ship husbandry task. The pattern readings were not disturbed.

Interaction between the patterns was tested by switching off first one and then the other. The pattern left on the air was unaffected. Leads from a junction box (type 9372) connect to the HF and LF receivers at the slave station. Changing round these leads was found to introduce a pattern variation of 0.03 lane, and it is therefore recommended that the leads should be labelled to prevent this happening accidentally.

RANDOM ERRORS

According to a Decca handbook the Hi-Fix counters may be affected not only by general pattern instability, already referred to, but also by short-term and long-term drifts. This certainly accords with the writer's experience although sometimes it has seemed that a pattern change has been so dramatic as to merit description as a pattern shift rather than a pattern drift. During the Hi-Fix trial a locking constant calibration was broken off half completed because the ship was heading for shallow water on a falling tide. The following day it was resumed with a good overlap on the previous day's work. The HF pattern locking constant was found to differ by 0.12 lane while the LF pattern locking constant remained unaltered. No reason was ever found for this shift.

When operating in the hyperbolic mode the monitor readings provide a good insurance against pattern drifts remaining undetected. Whether monitor fluctuations reflect accurately the pattern shifts in the survey area or not depends largely on the siting of the monitor station. The Canadians corrected their fixes for monitor deviations from the calibration value. If this procedure is adopted it is recommended that a sensible maximum be fixed; on reaching this maximum the chain would be recalibrated.

When operating in the two-range mode a monitor station is not practicable. The best check on pattern stability lies in comparing the readings of the lane identification display unit with the HF pattern. To do this effectively it is necessary to calibrate the HF and LF locking constants together, and then maintain those settings unchanged at the slave stations. This point is stressed because when the lane identification facility was first introduced it was suggested that the LF settings at the slave stations should be varied on a day-to-day basis to give agreement between the lane identification display unit and the HF counter readings. The bland assumption inherent in this practice that any error would be in the LF pattern while the HF pattern would always remain perfectly correct was hardly likely to appeal to the surveyor, and indeed in the instance quoted above the reverse was the case.

The recommended procedure is to note, at perhaps hourly intervals during the course of the survey, the difference between the lane identification display unit reading and the HF pattern reading. The sign of the difference is important. A daily mean can be obtained and compared with the days that follow. Any drift or shift in the mean indicates a pattern change. If, in addition, the comparisons are plotted geographically any trend on that account will be revealed. If desired, former comparison points could be revisited to check whether a pattern shift applied locally or generally.

EATON suggested a maximum likely error in a pattern reading of 0.12 lane. This error could occur equally, either positively or negatively, in both the HF and LF patterns. As far as the difference between the lane identification display unit reading and the HF pattern reading was concerned, such variations would mean that differences would always be within a 4.6-lane bracket. Anything in excess of 4.6 lanes would mean that a pattern drift or shift had occurred and that a new locking constant calibration should be carried out at once. Indeed, to be on the safe side, the writer would recommend recalibration if the daily mean varied by 3.0 lanes or more from previous daily means or if comparison at a point varied by 3.5 lanes or more from a previous check.

This method of monitoring the pattern can be used in the hyperbolic mode as well as the two-range mode.

It is interesting now to check EATON's figure of 0.12 lane maximum likely error by looking at some comparisons — lane identification unit reading minus HF pattern reading — actually obtained.

Set	*Number of comparisons*	*Maximum positive*	*Maximum negative*	*Equivalent maximum likely error*
I	197	+ 1.0	− 1.7	0.09
II	132	+ 2.7	− 2.4	0.14
III	132	+ 1.5	− 1.4	0.08
IV	67	+ 0.6	− 1.1	0.06

(The equivalent maximum likely error is taken from whichever of the maxima — positive or negative — was numerically greater).

The agreement seems to be good. By the writer's criterion set II would have been recalibrated. EATON uses his 95 per cent probability error of 0.10 lane in all calculations and this appears reasonable.

Having decided on a figure for random error of 0.10 lane and having worked out a method of ensuring that it cannot much exceed this value, it is necessary to consider what effect the error will have. In the two-range mode the random error in a fix depends on the random error in the Hi-Fix readings and the angle of cut of the position circles. In the hyperbolic mode the random error in a fix depends on the random error in the Hi-Fix readings, the angle of cut of the position hyperbolae and the lane expansion factors applicable to the hyperbolae at that point. The following formulae were worked out for EATON by Dr. W.S.B. PATERSON and enable accuracy lobes to be calculated and drawn :

Two-range

1. Inner :

$$\cos \beta = \frac{e \cdot L}{d}$$

2. Outer :

$$\sin \beta = \frac{e \cdot L}{d}$$

Hyperbolic

3. Front cover but outside the triangle formed by master and both slaves :

$$\sin \rho = \frac{e \cdot L}{d} \operatorname{cosec} \gamma$$

4. Side cover :

$$\sin (\rho - \gamma) = \frac{e \cdot L}{d} \sqrt{(\cot \rho + \cot \gamma)^2 + 4}$$

5. Inside the triangle formed by master and both slaves :

$$\cot \gamma = \cot \rho + \sqrt{\left(\frac{d}{e \cdot L}\right)^2 \sin^2 (\rho + \gamma) - 4}$$

ρ = $\frac{1}{2}$ (angle subtended by Pattern 1 master-slave baseline);
γ = $\frac{1}{2}$ (angle subtended by Pattern 2 master-slave baseline);
β = $\frac{1}{2}$ (angle subtended by the inter-slave baseline);
L = landwidth on baseline;

e = Hi-Fix error (say 0.10 lane if EATON's figure is accepted);
d = greatest possible acceptable shift as decided by the surveyor.
In formulae 4 and 5 it is necessary to work several approximations of ρ and γ until both sides of the equation agree.

It is suggested that the surveyor decides on the greatest possible shift that he can accept on the scale on which he is working, and then constructs the limit contours from the above formulae. This may reveal that in order to complete the survey it will be necessary to resite some Hi-Fix stations. If the limits are drawn on the field sheet the surveyor can regard them as zones of discretion — to be approached and possibly exceeded on a day when Hi-Fix conditions are good but to be avoided when conditions are unstable. Areas close to the limit where the lane width of one pattern is much wider than the other are especially dangerous when working in the hyperbolic mode in poor conditions.

Having considered random error at some length it is worth recalling at this stage that a major source of systematic error — uncertainty as to the proper value of phase lag factor (velocity of propagation) — is not allowed for at all in the above analysis. An additional margin of error should be allowed for this, and the allowance will depend on mode of operation, distance from Hi-Fix stations and what checks on phase lag factor have been possible.

MAINTENANCE OF CORRECT WHOLE LANE NUMBER

Unless whole lane number is correctly maintained other errors pale into insignificance.

The failure of the lane identification facility to live up expectations in the Antarctic has already been referred to. This prompted the writer to collect data. If failure is defined as a lane identification unit reading differing by 0.50 lane or more from the correct HF pattern reading the following results were obtained :

Set	*Number of comparisons*	*Number of failures*	*Failure rate %*
I	197	78	40
II	132	73	55
III	132	48	36
IV	67	5	7
Overall	528	204	38

However the picture is not as black as these results might indicate. If the procedure of recording the difference between the lane identification display unit reading and the HF pattern reading is followed a relationship will probably emerge which, over a short period, would allow lane to be set with a fair degree of confidence.

For the certainty the surveyor requires, other means must be sought. Suggested methods are by :

1. Horizontal sextant angle check fixes. These are really only accurate enough (unless computed) when plotted on scales of 1/50 000 or larger, and only then if really well-conditioned fixes are available.

2. Using moored buoys or surveying beacons. The technique here is to approach the buoy along the lane of the pattern being checked and to set or check the counter when about two cables off. As a preliminary it is, of course, necessary to transfer readings to the buoys and this should be done when they are in both their ebb and flood positions, and the appropriate reading used thereafter. One buoy or beacon should not be used too many times consecutively in case it has dragged.

3. Using radar. Favourable reports are being received of the use of radar in association with a transponder beacon to set up whole lane number. If the survey is within radar range of the slave stations, or nearly so, the transponders can be installed one at each station. In the two-range mode comparison between radar range and Hi-Fix reading would then be direct. However if the transponder was installed elsewhere it would not be difficult to arrange to cross both transponder range circles and Hi-Fix position circles or hyperbolae at 90° and so obtain a series of comparisons.

4. Crossing the master-slave baseline extensions. In the hyperbolic mode the baseline extensions can sometimes be crossed. If the crossing is at the slave end then the whole lane number on the counters should equal the number of lanes on the base line, and if the crossing is at the master end then the whole lane number should be zero.

5. Using a sonar bottom beacon. In a sonar fitted ship it is possible to lay a bottom beacon and set or check the Hi-Fix whole lane number by its use. The chief proponent of this method used to train his sonar set on the beam and pass close by the beacon on a course that cut the lanes at 90°. The Hi-Fix reading was set or checked when the response from the beacon reached its maximum.

6. Using the known position of wrecks. In a sonar fitted ship working in home waters where wrecks are numerous, this method is not as fanciful as might be supposed. The wrecks have to be charted anyway, and if their Hi-Fix coordinates are found early in the survey the information can be put to good use in this way. As a large wreck may span several Hi-Fix lanes the safest method is to draw up a large-scale Hi-Fix plot of it. Lane would then be set when on top by echo-sounder and any possible ambiguity resolved by a second or third crossing.

To guard against lane slip while engaged in surveying operations it is undoubtedly safest to run the lines along one pattern and to fix at whole lane number intervals of the other. Lane slip in the line-keeping pattern would then show as an unaccountable side-step while lane slip in the fixing pattern would give rise to an irregular fixing interval which would show up in the timing or in the fixing interval on the echo trace if an echo-sounder was in use.

The lane identification display unit is a great help in monitoring for lane slip. If a single lane slip occurs in either HF or LF pattern this gives rise to a 10-lane slip in the unit. If, as has been recommended, careful record has been made of difference between the lane identification display unit reading and the HF pattern reading before the lane slip then the matter can be totally resolved by making a further comparison after it has occurred and applying the following rules :

1. If the difference has changed by 9.0 lanes then the HF pattern has slipped.

2. If the difference has changed by 10.0 lanes then the LF pattern has slipped.

3. If the difference has increased then either the HF pattern has gained a lane or the LF pattern has lost a lane (see 1 or 2).

4. If the difference has decreased then either the HF pattern has lost a lane or the LF pattern has gained a lane (see 1 or 2).

e.g. Correct readings :	HF	130.12
	LF	117.04
	LID	130.8
	LID – HF	0.68
If HF gained 1 lane :	HF	131.12
	LF	117.04
	LID	140.8
	LID – HF	9.68
If HF lost 1 lane :	HF	129.12
	LF	117.04
	LID	120.8
	LID – HF	8.32
If LF gained 1 lane :	HF	130.12
	LF	118.04
	LID	120.8
	LID – HF	– 9.32
If LF lost 1 lane :	HF	130.12
	LF	116.04
	LID	140.8
	LID – HF	10.68

With experience multiple lane slips or combined HF and LF lane slips can be resolved with confidence. However it is good practice to record all corrections made to the various counters, so that an error made in the heat of the moment can be allowed for later.

CONCLUSION

In the early days of the radio position-fixing systems breakdown was frequent. Almost all the most suitable surveying days seemed to be spent standing forlornly over some young radio engineer who had the set in pieces before him.

The position is different now. Equipment works only too well and such a volume of work is possible that new methods of automatic data logging and automatic chart production are having to be devised.

The surveyor has recognised his responsibilities — which are the same for any new equipment, whether electronic, sonic or optical.

First, it is necessary to determine the errors and limitations of the new equipment, not as they are in the manufacturer's laboratory but as they are on the survey grounds in the North Sea, the Antarctic and the Persian Gulf. With Hi-Fix the surveyor is concerned with phase lag factor (or velocity of propagation), with land path errors, with pattern stability and random errors and what effect they have on the accuracy of the finished chart. Much still remains to be found out.

Secondly, it is necessary to see if there are any difficulties in the day-to-day operation of the new equipment and to devise methods of overcoming these difficulties. With Hi-Fix it is suggested that the chief difficulty is the maintenance of whole lane number with complete certainty at all times. This article makes its contribution towards solving this problem.

Finally it is necessary to work out the best and most efficient method of using the new equipment so that full advantage is gained from it. This article has only touched on this aspect in passing, and one point has deliberately been left until the end because it may still not be as thoroughly appreciated as it ought to be. Hi-Fix is light — a slave station with all accessories weighs less than a ton. It is also easily erected and calibrated. It should therefore be normal practice to move the chain as often as may be necessary to cover a survey area accurately. Land paths, poor angle of cut between the patterns or a large lane expansion factor should never be accepted if they can be overcome by moving either a station or the whole chain. The Canadians appreciate this, and EATON remarked that the survey of Hell Gate which was done with two chains would, in the light of subsequent experience, have been better done with five or six.

REFERENCES

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