OPERATIONAL REPORT
ON THE DECCA LAMBDA SYSTEM

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I.H.B. Note. — The authors were respectively captain and navigating officer of H.M.S. *Vidal* (figure 1).

Introduction

Lambda (Low AMBiguity DeccA) is a logical and much needed development of the well-known two-range Decca position fixing system for hydrographic surveying. The principal improvement is the provision of a lane identification facility, which, on activation by the master, indicates the observer's position with no ambiguity within a zone about 10 kilometres wide. Thus the master's position is only required to be known to within three nautical miles to be able to line up the system initially. Other advantages are increased robustness and compactness of the equipment, and complete interchangeability of the two slaves whose units are identical.

The system has been used successfully at ranges of up to 150 nautical miles with no observed reduction in signal strength. The maximum range is probably of the order of 300 nautical miles, though at this distance the lane identification facility would probably be operating at reduced efficiency.

Theory of Lambda

The basic measuring process of Lambda is the same as for two-range Decca, namely the phase comparison of an outgoing master signal with the returning slave signal, the two being phase locked at the slave.

All Lambda frequencies are multiples of a basic frequency f, which is never transmitted, of the order of 14 kc/s. The master transmitter in the surveying ship radiates a continuous wave signal of frequency $12\,f$, derived from its basic $1\,f$ oscillator. The slave stations ashore also contain a $1\,f$ oscillator, whose twelfth harmonic is locked to the received master transmission of $12\,f$. They in turn re-radiate signals of $8\,f$ (red slave) and $9\,f$

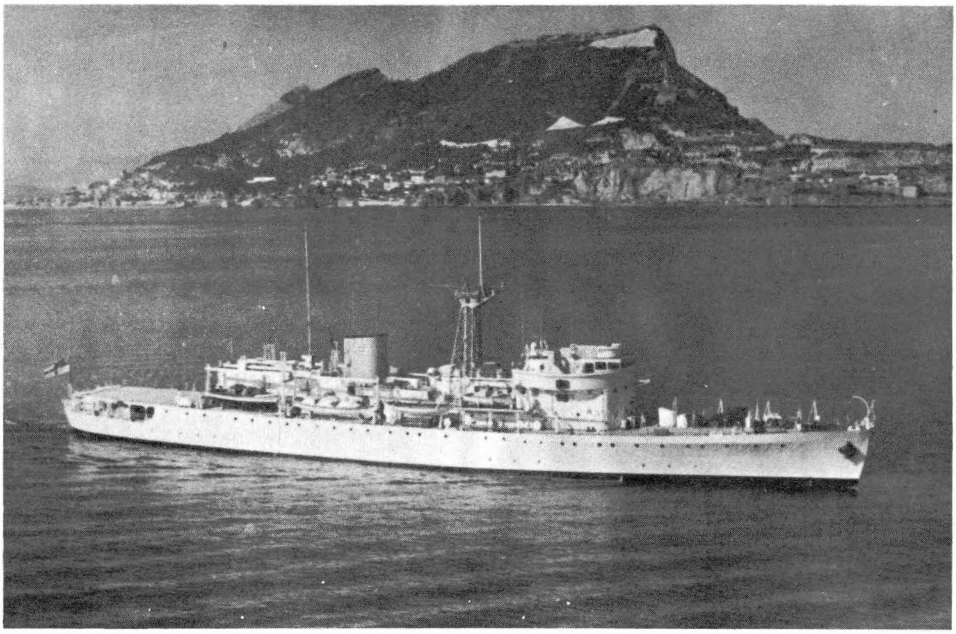


FIG. 1. — H.M.S. *Vidal*.
One of the Royal Navy's Lambda equipped surveying ships (note master transmitting mast abaft funnel).

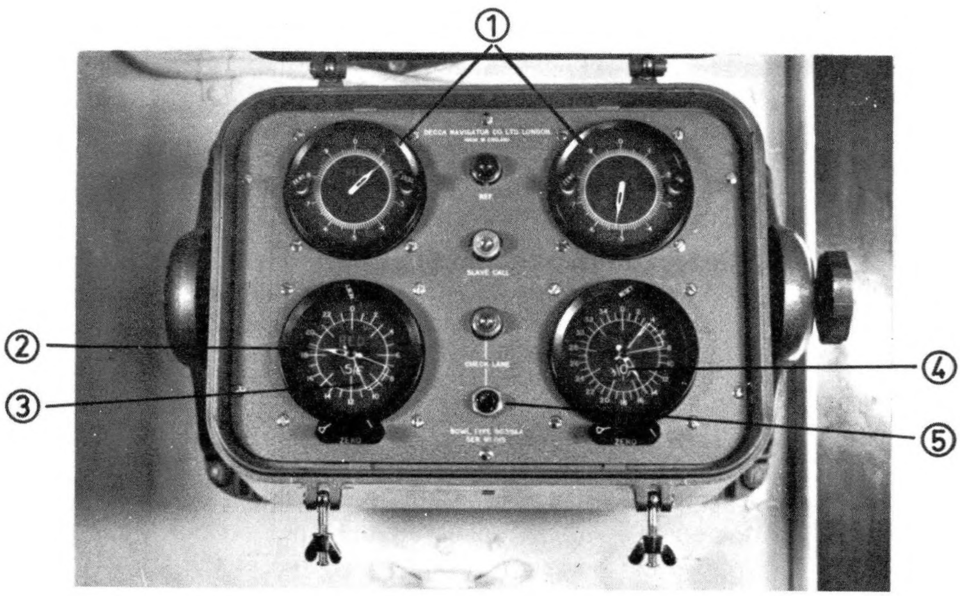


FIG. 2. — Lambda Decometer.

1 : Fractional decometers
2 : Whole lane pointer
3 : Lane ident. sector
4 : Zone number
5 : Lane ident. push button

(green slave). The slave and master signals are phase compared in the master receiver in the ship at two frequencies (8 *f* and 24 *f* for red, 9 *f* and 36 *f* for green), the results being used to drive four phase difference indicators or decometers, at the ship's plotting position.

Figure 2 shows these decometers, the left hand pair being red and the right hand green. The fractional decometers, one revolution of which represents a whole lane, are driven from the 24 *f* and 36 *f* comparisons. This gives lane widths of approximately 420 and 280 metres (the exact value depending on the 1 *f* oscillator frequency, but the green lane width is obviously always exactly two-thirds of the red).

The 8 *f* and 9 *f* comparisons are used to drive the whole lane pointers on the lower pair of dials, but are geared down in the ratio of 8:1 and 9:1 respectively, so that the pointers will move 3 red and 4 green lanes for each complete phase shift of 8 *f* and 9 *f* frequencies, and one complete revolution for every " zone " of 24 red lanes or 36 green. The width of the zones, measured along the line master to slave, is in both cases about 10 000 metres.

The zone in which the master is situated is indicated by the small figure in the centre of the lower dials, the numbers ranging from 0 to 9 and then repeating; this is driven purely mechanically by the lane pointer, and has to be set up correctly at the beginning of operations.

Figure 3 shows the basic phase-comparison process for the red slave in diagrammatic form. It should be noted that although there are twelve positions at which the 12 *f* signal at the slave can be locked to the received 12 *f* master signal, at only one of these positions will the 1 *f* oscillators of master and slave be in phase. As will be seen below, the correct operation of lane identification and whole lane pointers depends on the correct locking or " notching " (as it is termed to avoid confusion with the 12 *f* phase locking) of these two 1 *f* patterns.

The notching process

Notching is achieved by pressing the check lane button on the decometer box and thus momentarily transmitting 11 *f* from the master, and comparing this signal received at the slave with the eleventh harmonic of the latter's 1 *f* oscillator. The result of this 11 *f* comparison is displayed at the slave on a " notch meter " which indicates the correction required to bring the station into notch. As the slave 1 *f* oscillator can be held in any one of twelve positions by the 12 *f* phase locking (see figure 3 where the slave 1 *f* is shown two 12 *f* wavelengths out of phase), it will be seen from figure 4 that at only one of these positions will the 11 *f* frequencies (and thus the 1 *f* frequencies) be in phase. The slave is brought into notch by the slave operator turning the notch goniometer the appropriate number of " clicks " to the right or the left, as indicated on the notch meter until it reads zero. The correctness or otherwise of this adjustment can be checked on the receipt of the next lane identification signal.

Referring again to figure 3, it will be seen that the two 8 *f* frequencies

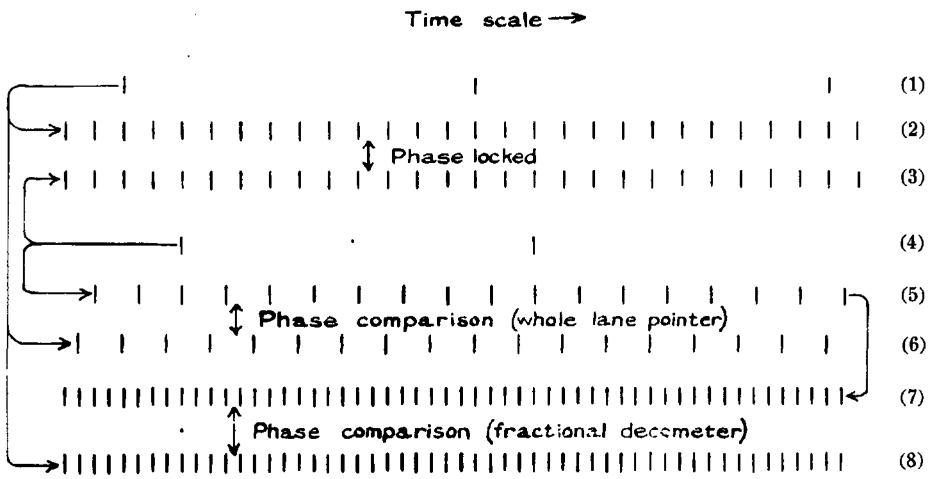
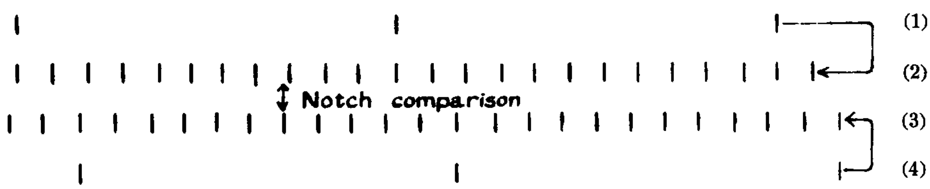


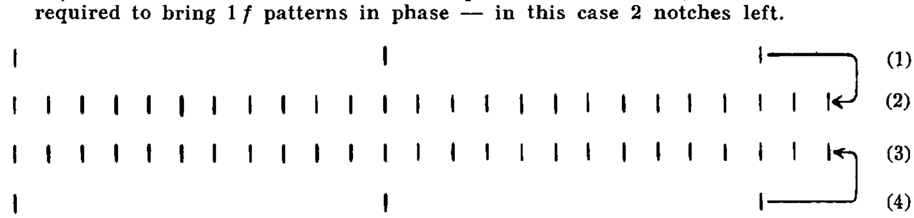
FIG. 3. — Basic red slave measuring process.

Note : For clarity this diagram shows the position when the master is a whole number of 1 *f* lanes from the slave.

(1) Master 1 *f* oscillator
(2) Transmitted master 12 *f* signal
(3) 12 *f* at slave, phase locked to received master signal
(4) Slave 1 *f* oscillator (not correctly notched)
(5) Transmitted 8 *f* slave signal
(6) 8 *f* derived from master 1 *f* oscillator
(7) 24 *f* derived from incoming slave 8 *f* signal
(8) 24 *f* derived from 1 *f* master oscillator



(a) Position as in fig. 3, i.e. 12 *f* transmissions from master and slave in phase, but 1 *f* slave oscillator 2/12 wavelength late on master 1 *f*. " Notch " meter, operated from 11 *f* transmissions, shows difference of phase between them, and hence movement required to bring 1 *f* patterns in phase — in this case 2 notches left.



(b) Correctly notched. 1 *f* and 11 *f* both in phase, notch meter showing zero.

FIG. 4. — Notching process.

(1) Master 1 *f* oscillator
(2) 11 *f* transmission received from master
(3) 11 *f* from slave 1 *f* oscillator
(4) Slave 1 *f* oscillator

are shown out of phase by 120°, and thus the whole lane pointer will be one lane in error. If the slave 1 *f* frequency is moved one notch (equivalent to a 12 *f* wavelength) to the right, the 8 *f* frequencies will be in phase, making the whole lane pointer relatively correct within a three lane sector, but the slave is still not notched correctly as the 1 *f* frequencies are out of phase. In fact, the slave 1 *f* frequency needs to be moved two notches to the left from the position shown on the diagram, to make 1 *f*, 8 *f* and 24 *f* in phase. Thus it is essential for the slave to be correctly notched to ensure that the whole lane pointer is correct, although there is a 1 in 3 chance of its being correct at any given notch (for the green slave this is a 1 in 4 chance). Incorrect notching will have no effect on the fractional lane pointer, though it will make a complete revolution every time the slave notching meter is moved one click.

As well as giving the slave operator an indication of this notching, the pressing of the check lane button initiates the lane identification sequence. On reception of the 11 *f* signal from the master, the slaves momentarily interchange frequencies, i.e., the red slave transmits 9 *f* and the green 8 *f*. At the master receiver, 8 *f* and 9 *f* locked oscillators preserve the phase of the slave signals normally controlling them, and these are mixed with the received 9 *f* and 8 *f* signals from the slaves to obtain a 1 *f* beat frequency, thus the same effect is achieved as if 1 *f* had actually been transmitted from the slaves. This beat frequency is phase compared with the basic master 1 *f* and the output is used to drive the lane identification sector pointers on the decometers. Thus, as two 1 *f* oscillators are locked on by notching, the correct lanes are indicated within a red zone of 24 lanes or a green zone of 36 lanes.

As the whole lane pointers are geared down in ratios of 8:1 and 9:1 for red and green respectively, there are 8 and 9 positions which they can take up on the decometer. The correct one is indicated by the lane identification sector-shaped pointer (after the initiation of a lane identification sequence), and it is only necessary to set the whole lane pointer to within the group of three (red) or four (green) covered by the lane identification sector, for it to take up the correct lane.

On initial setting up of the system, it is recommended that a series of 15 lane identifications be transmitted, at not less than 15 second intervals, so that the slave operators can be sure that they are in notch. If further lane identifications are required, they can be requested from the slaves by pressing their notch request buttons, which will light the slave call bulb on the decometer, and also the appropriate alarm bulb on the master control unit (indicating which slave is calling) and ring the alarm bell.

Notch indication error

At each slave station the receiving aerial is well within the induction field of the transmitting aerial, the resulting interference causing the slave 1 *f* oscillator to be held 1/24th of a cycle out of phase with the master 1 *f*. This will have the effect of indicating a half notch error in the displayed notch reading. This error is arbitrarily assumed to be positive, and is corrected by adding four hundredths (the nearest calibration to 1/24th) to the slave lane identification goniometer setting, after first referencing the goniometer to zero.

Operational experience shows that the incorrect setting of the notch indication error, or neglect to do so, is one of the commonest operational faults, resulting in the notch indicator remaining half-way between graduations and consequent uncertainty at the slave station as to when a true zero reading is shown. It is therefore essential to ensure that, when the slaves are operating, the notch indication error is applied in the same sense as when the stations were calibrated.

The same error will also affect the decometer pointers at the master, but is automatically allowed for when the stations are calibrated, as described below.

Slave stations

The requirements of a slave site for Lambda are the same as for two-range Decca, and the 100-foot transmitting mast and power requirements are identical.

It is essential, due to the complications of notching and lane identification as well as for administrative reasons, to have reliable communications between the master and slaves. It is strongly recommended that the slaves be equipped with radio capable of maintaining radio-telephone contact to a range of at least 150 miles.

The slave installation consists of two receiving aerials, two slave control units (one operating and one at immediate stand-by) and associated power supply units, a slave transmitter and a tank unit, an aerial coil box and a 100-foot transmitting mast, together with a 2 kilowatt power supply.

Master installation

The 45-foot master transmitter mast is identical with the two-range Decca mast, and the layout of the master equipment is similar to two-range Decca. The two master control units with associated decometers and the track-plotter are situated on the bridge or other plotting position (see figure 5) and the transmitter itself is installed elsewhere as convenient.

Locking constant

The reasons for, and causes of, the locking constant in two-range Decca are well known, and the same errors are inherent in the Lambda installation. By convention, two-range Decca locking constant is always positive and less than one, i.e., whole lanes of error are ignored. However, with the introduction of lane identification, the total locking constant, including whole lanes, must be considered.

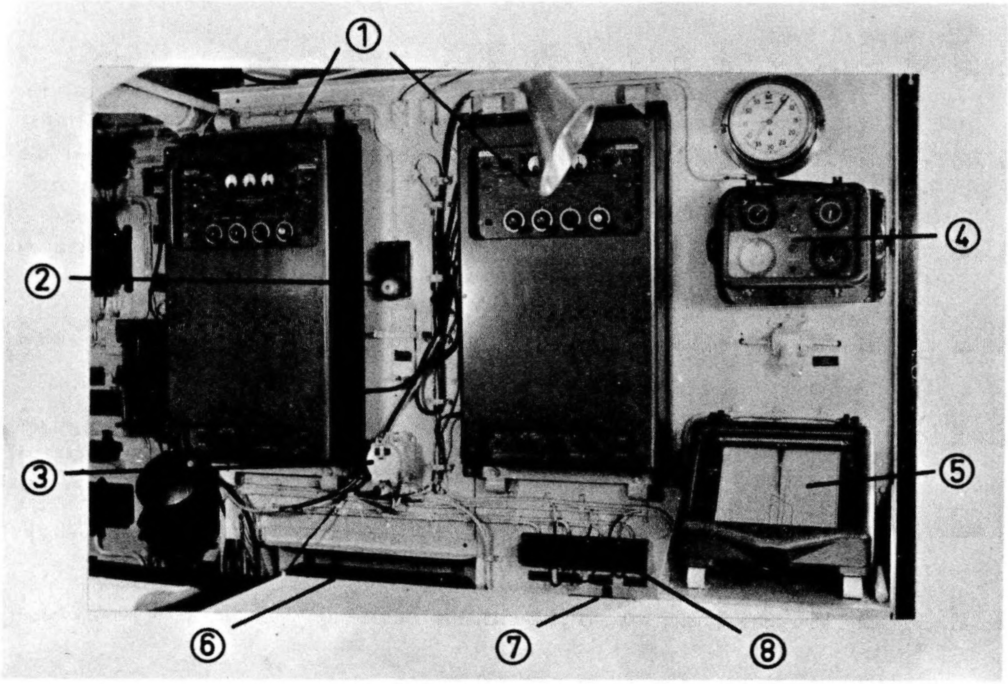


FIG. 5. — Master installation at plotting position.
1 : Master control units
2 : Alarm bell
3 : R/T connection
4 : Decometers
5 : Track plotter (control amplifier under)
6 : Power supply units (hidden)
7 : Telephone to transmitter and mast (hidden)
8 : Power supplies

The locking constant is made up, *inter alia,* of a master (12 *f*) radiated phase error (LM) and a slave (8 *f* or 9 *f*) radiated phase error (LS). But the lane identification facility is only affected by the 12 *f* phase error (LM), so it is necessary to ascertain not only the total locking constant (LM + LS) but also LM alone. In fact this is relatively simple, and is best illustrated by an example.

The true range of the ship from (say) the green slave is known, and when converted to green lanes is 33.46.

At the instant of taking the range, the reading of the whole lane and fractional decometers was 29.84, hence :

$$(LM + LS) = 33.46 - 29.84 = + 3.62$$

(But it should be noted that the reading could equally well be taken as four lanes higher, i.e., 33.84, in which case (LM + LS) would be —0.38; either value is correct.)

At the same time, the mean of a series of lane identification sector readings was taken and was found to be 31.0, hence :

$$LM = 33.46 - 31.0 = + 2.5$$

Allowance of errors

Either these errors can be allowed for when drawing the Lambda grid pattern, or the decometers can be offset to show the correct readings. In either case the lane identification sector indicator must be corrected to bring it into sympathy with the whole lane pointer. In practice, it is found desirable to draw the Lambda range circles on the plotting boards uncorrected for the locking constant, so that the survey work can start with the minimum of delay as soon as the slave stations are erected and calibrated, hence the latter method is usually employed.

These corrections are then applied as follows :

(*a*) Fractional decometer pointer.

Reference to zero with the goniometer, then rotate the goniometer 0.62 anti-clockwise (clockwise on the decometer, giving a reading of 0.62).

(*b*) Whole lane pointer.

Reference 3.62 lanes clockwise of any lane number divisible by four (marked by long lines on the dial).

(*c*) Lane identification sector pointer.

Reference 2.5 lanes clockwise of zero.

To avoid confusion with signs and for subsequent check referencing, it is recommended that the correct referencing positions be displayed near the decometers in the following form :

REFERENCING POSITIONS — GREEN

Fractional	: 0.62
Whole lane	: 3.62, 7.62, 11.62, 15.62, 19.62, 23.62, 27.62, 31.62, 35.62.
Lane identification	: 2.5

As with two-range Decca, these corrections are liable to vary with change of bearing from the slave station, and this can be allowed for in the usual way.

Calibration

The calibration of Lambda is carried out in exactly the same fashion as with two-range Decca : the ship steams slowly over the survey arc, some ten miles or so from the slave station, while simultaneous fixes and Lambda readings, including lane identifications, are obtained.

The position of the ship can either be ascertained from theodolite intersections from shore or sextant resections on board, or else a range from the station being calibrated can be measured by electronic means (tellurometer, Hydrodist, etc.). The latter method is undoubtedly quicker and easier, although it has the slight disadvantage that the calibration fixes for one slave cannot be used as a check on the calibration of the other, unless an accurate bearing is obtained at the same time.

Tellurometer calibration

A tellurometer has in fact been used successfully for calibration with the ship under way, and this was found to be a quick and simple method. Having decided between what bearings the calibration is required, observations were obtained at approximately ten-degree intervals over the required arc. Before each observation, the ship's course was adjusted so that it was approximately at right angles to the bearing of the slave, i.e., so that the rate of change of range was small. Final adjustments to the course steered were made with reference to the A+ reading of the tellurometer so that a slow rate of revolution of the A+ value was obtained. To simplify calculation, it was found best to adjust course so that a more or less steady increase or decrease of A+ was maintained. Crossing the T of the bearing exactly, so that A+ first decreases and then increases, is not recommended.

The tellurometer measuring technique has to be somewhat modified to allow for the ship's movement. A—, A+ reversed, and A— reversed are not used, so it is important that the circle displayed on the cathode ray tube be properly centred before starting operations.

A series of seven readings, namely A+, D, A+, C, A+, B, A+, constitutes one fix, the intervals between each individual reading being constant.

The transit time is calculated by accepting the first A+ reading as the true value, and the moment of taking this reading is the moment of the fix. The two A+ readings either side of the D, C, and B readings are meaned, and the D, C, and B values are subtracted from these meaned values to obtain the remaining uncorrected figures of the transit time. To reduce these three values to the time of the fix, the differences between the initial A+ reading and the appropriate mean A+ values are divided by 10, 100 and 1 000 for the D, C, and B patterns respectively, and the results thus obtained are applied to the figures found initially. In practice this correction is only significant in the case of the D pattern.

Generally a series of three fixes is taken consecutively, such that the last A+ reading of the first becomes the first A+ reading of the second fix. Provided that the ship's course and speed are constant, this should produce nearly equal differences between the three measured distances.

Lambda readings of the slave being calibrated should be recorded at the same moment as the first A+ reading for each series, and it is recommended that a lane identification be obtained immediately after the third fix. The true bearing, by gyro compass, should also be recorded for each series of fixes.

Conversion of tellurometer transit times to Lambda lanes, due allowance being made for short range phase lag, then gives the value of the locking constant. The three values obtained in each series should be meaned, obviously erroneous ones being rejected, and the results should be plotted against bearing to give the usual locking constant curve.

In practice it may not always be possible to set up the remote tellurometer at the exact electrical centre of the slave station, but any correction thus needed can be obtained by measuring distance and bearing to the tellurometer from the electrical centre and obtaining the correction for each series of fixes from a graphical plot.

Example of calibration with the tellurometer

Date : 12. 2. 1962 — Bearing of green slave : 133°
Time: 1015 — Tellurometer A reading : decreasing

Fix No.	Pattern	Reading	A+ means	Initial difference	Correction	Final difference	Transit time
1	A+	65					130 565
	D	09	59,5	A-D 50,5	$+\frac{5,5}{10} = 0,5$	51	
	A+	54					
	C	39	46,5	A-C 07,5	$+\frac{18,5}{100} = 0,2$	07,7	
	A+	39					
	B	00	33,5	A-B 33,5	$+\frac{31,5}{1000} = 0$	33,5	
2	A+	28					130 528
	D	74	25	A-D 51	$+\frac{3}{10} = 0,3$	51,3	
	A+	22					
	C	17	20	A-C 03	$+\frac{8}{100} = 0,1$	03,1	
	A+	18					
	B	87	17	A-B 30	$+\frac{11}{1000} = 0$	30	
3	A+	16					130 516
	D	66	15	A-D 49	$+\frac{1}{10} = 0,1$	49,1	
	A+	14					
	C	09	14	A-C 05	$+\frac{2}{100} = 0$	05	
	A+	14					
	B	81	14	A-B 33	$+\frac{2}{1000} = 0$	3	
	A+	14					

Fix No.	Transit time	Distance in metres	Correction (1)	True distance	Distance in lanes	Decometer reading	Locking constant
1	130 565	19 564	+40	19 604	1/33.48 (2)	1/29.88	+3.60
2	130 528	19 559	+40	19 599	1/33.46	1/29.84	+3.62
3	130 516	19 556	+40	19 596	1/33.45	1/29.81	+3.64

(1) Distance from satellite station to electrical centre.
(2) i. e., One zone + 33.48 lanes = 69.48 lanes.

Therefore mean locking constant for bearing 133° = + 3.62.

The observed lane identification reading is 31.0; therefore the lane identification correction is + 2.5.

Plotting the Decca lattice

The radii of Lambda curves are calculated from the red and green lane widths, due allowance being made for long range phase lag and the scale factor of the projection in use, as with two-range Decca. The number of lanes which are drawn will depend on the scale of the survey, but it is recommended that the intervals on the plotting sheet should be about an inch. For ease of plotting the fixes, it is best that the same lane interval be used for both slaves, which means that the red intervals on the sheet will be half as much again as the green.

When operations are carried out fairly close to the slave stations, it is usually possible to draw the Decca lattice direct with beam compasses. However, when the survey area is at a greater distance from the slaves, the construction of the lattice will necessitate the drawing of a family of circles, whose radii are too large to set on a beam compass. To simplify this operation, standard circle sheets have been prepared in the Hydrographic Department of the Admiralty, printed on transparent Cobex plastic, and varying in radius from 20 centimetres to 10 metres; they are spaced 2 centimetres apart and the complete family is shown on twelve sheets. Each sheet, besides the circular arcs, carries a number of radial lines.

It is therefore a simple matter to calculate and plot a series of fitting-on points for the requisite standard circles to cover the particular survey area, and thus to transfer the standard circular arcs to the plotting sheet. Points on the Decca lattice circles, concentric with the standard circles, can then be plotted from the nearest standard circle by offsets and the circles drawn in with splines.

For plotting the ship's position it is recommended that a cursor be made from Perspex or similar transparent material as shown in figure 6. In this example it is designed for a scale of 1/100 000, at which scale every sixth lane was drawn on the plotting sheet. The semi-circles represent one red or green lane for a chain of $12f = 177.066$ kc/s.

To use the cursor it should be placed on the sheet with the centre line pointing about midway between the slaves, the red lane semi-circles being on the same side of the centre line as the red slave. The value of the next lower plotted lane below the Lambda reading at the fix is then mentally subtracted from the reading at the fix, and the cursor is adjusted, interpolating by eye as necessary, until the corresponding semi-circles are tangential to the appropriate curves on the plotting sheet; the ship's position is then at the centre of the cursor. (In the case of figure 6, the readings are 1/20.9 red and 2/28.0 green).

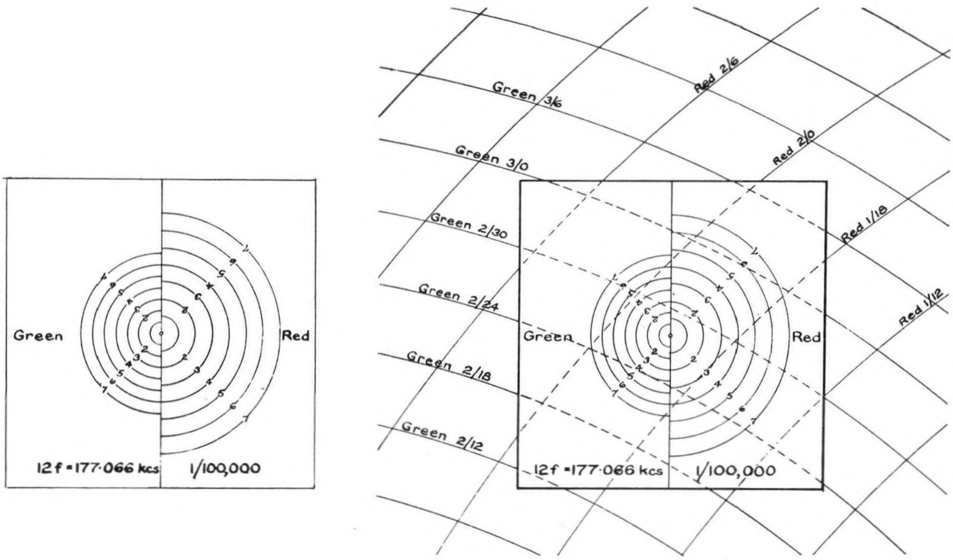


FIG. 6

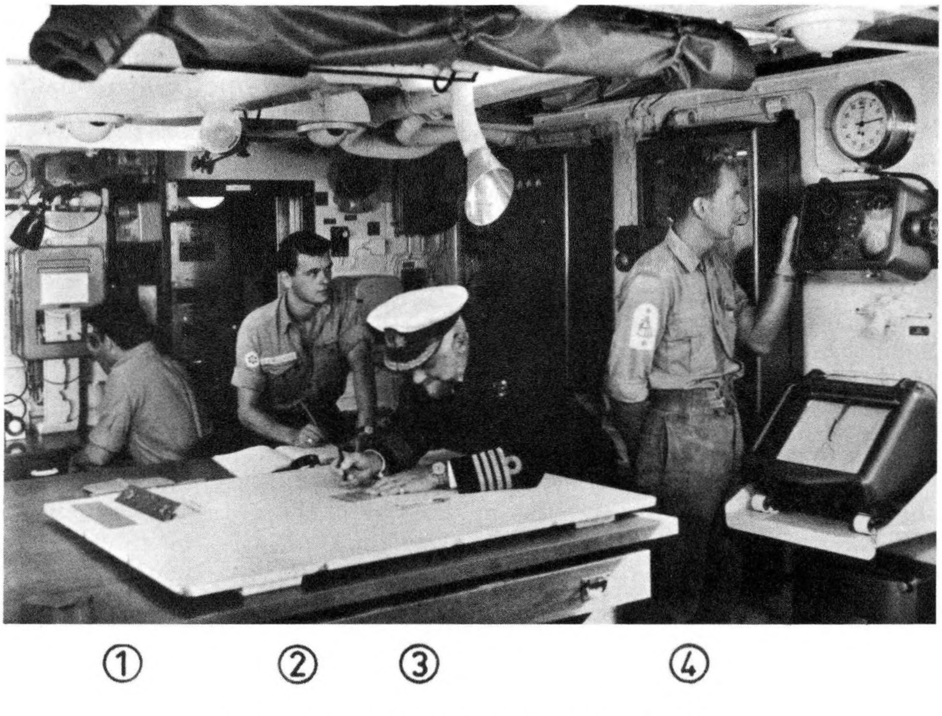


FIG. 7. — Lambda controlled survey in progress.

1 : Echo reader
2 : Writer down
3 : Officer in charge
4 : Decometer reader

Practical operation of Lambda

Experience has shown that the correct operation of the lane identification facility requires a considerably higher degree of electronic knowledge and capability than with basic two-range Decca. As has been explained above, incorrect notching can very easily lead to the chain being one or two lanes in error - an error which is not easily detectable without alternative methods of fixing. For this reason it is recommended that reference beacons be used for checking the pattern at least twice a day when surveys are being conducted out of range of land fixes.

Heavy showers have often caused the slaves to lose lock and, after the rain has ceased, some difficulty has been found in notching.

There is no doubt, however, that Lambda is a considerable advance in two-range Decca, and, with practised operators who have a high degree of technical knowledge, it forms a reliable fixing system for hydrographic surveys.