A HI-FIX SURVEY IN THE SOUTH ORKNEY ISLANDS

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1. The Surveying Service of the Royal Navy has recently acquired several Decca Hi-Fix Type B/M equipments. One outfit has been installed in the Royal Research Ship *John Biscoe* for use in Antarctic waters. The British Antarctic Survey, who are responsible for the operation of the R.R.S. *John Biscoe,* agreed that a proportion of the vessel's time during the 1964-1965 season should be devoted to hydrographic surveying and accommodation was found on board for a surveying officer, his assistant and three Decca engineers.

South Orkney Islands

2. South Orkney Islands are a group of islands north east of the Antarctic Peninsula. The British Antarctic Survey Base there is on the shore of Borge Bay on the east coast of Signy Island. There a wide programme of biological research is underway. With the growth in the importance of this Base the need was felt for an improvement in the charting of the area — both of Borge Bay itself and of the approaches to Signy Island. Any new hydrographic work would be incorporated with recent land survey work on Signy Island and Coronation Island which has resulted in the publication of a new map of the Western Islands of the group showing much new coastal and topographical detail.

3. In December, 1964, a large scale survey of Borge Bay (1/12 500) was carried out by a Naval party living under canvas in the area of the B.A.S. Base. A properly equipped launch was used for this work, conventional methods were employed and the survey was completed expeditiously under ideal conditions.

4. In January, 1965, a survey of the approaches to Signy Island on 1/50 000 was begun. This area had previously been decided as representing priority work in the group of islands, although there was certainly no expectation of completing so much in a single season. The R.R.S. *John Biscoe* and her Hi-Fix equipment were used while the surveying launch worked in the more dangerous inshore waters.

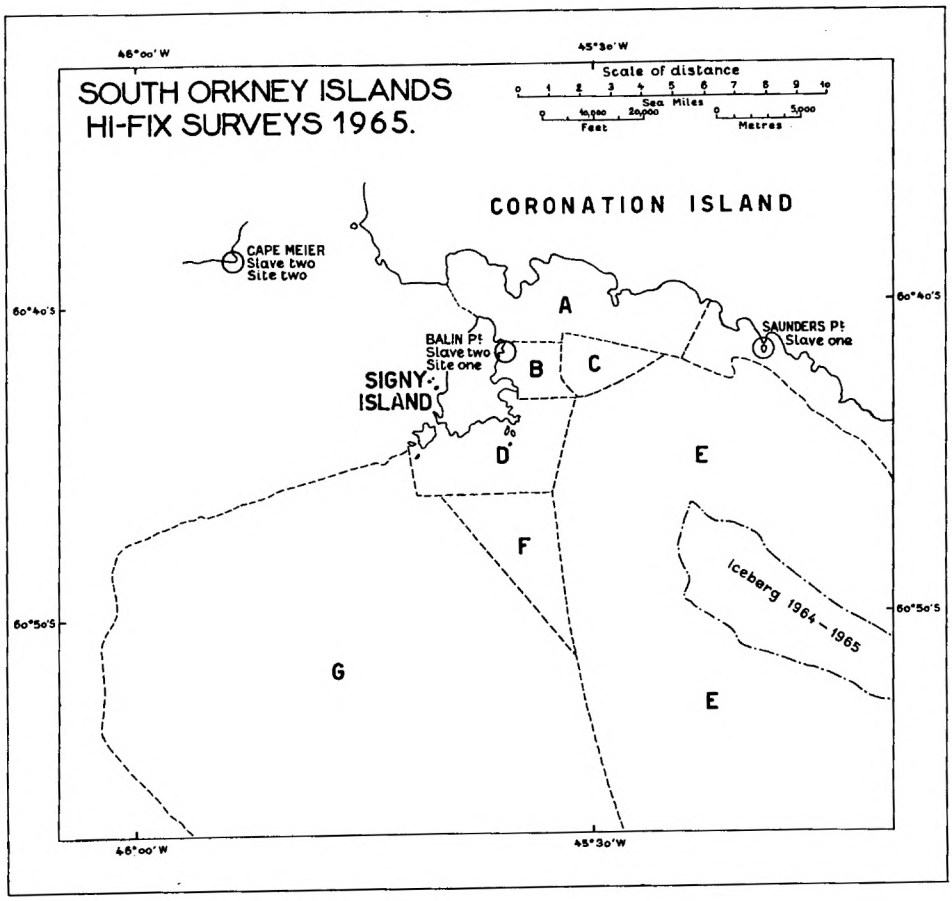

FIG. 1

A : Sounded by boat
B : Large scale survey
C : Sounded visually
D : Sounded by boat
E : Sounded using Saunders Point and Balin Point slave stations
F : Sounded using Saunders Point slave station and visual cut off angle
G : Sounded using Saunders Point and Cape Meier slave stations.

Preliminary work

5. A reasonable triangulation existed for Signy Island — but even this had been carried out in the Antarctic winter and was based on a short distance measured across the sea ice. The arrival of H.M.S. *Protector* equipped with two Whirlwind helicopters in support of the survey party allowed new triangulation to be undertaken expeditiously. Three peaks of Signy Island were occupied and all the angles and sides of a base triangle were measured (the latter by using Hydrodist instruments in the telluro-

meter mode). This revealed errors of 1/1 000 in the previous work. Five points on the south coast of Coronation Island were then fixed with relation to the Signy Island stations — in each case all angles and distances were observed and stations co-ordinated on the basis of a semi-graphic plot with an apparent accuracy of ± 1 metre out to the furthest station at 26 kilometres.

Selection of sites for Hi-Fix slave stations

6. Hi-Fix was to be operated as a two-range system. A glance at the chart shows the peculiar problems posed by the south coast of Coronation Island if the sea area is to be covered effectively and a land path over Signy Island avoided. Furthermore the south coast of Coronation Island eastwards of Signy Island must be one of the most iron-bound coasts in the world — cliffs 1 000 feet high alternate with deeply crevassed glacier fronts along almost its entire length.

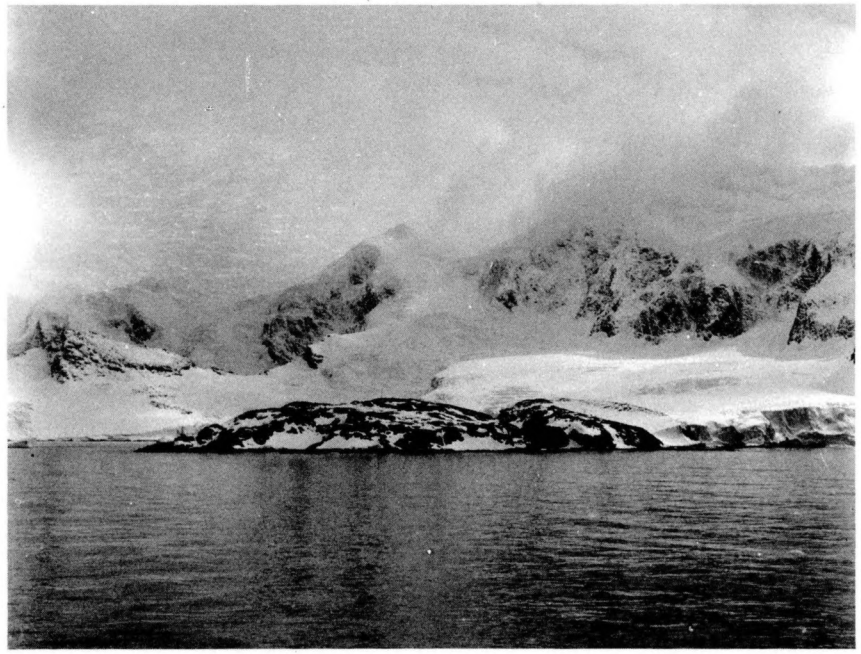

FIG. 2. — View of Saunders Point, site of Hi-Fix slave station. The tents of the Hi-Fix Camp can be seen below and to the left of summit. In the background is the coast of Coronation Island.

7. In the end it was decided to establish one slave station on Saunders point (really an off-lying island) and the other at Balin Point. This gave good Hi-Fix cover over the area east of Signy Island (except close to the inter-slave baseline where it was perfectly feasible to fix by horizon-

FIG. 3. — View of Balin Point, site of Hi-Fix slave station. The tents of the Hi-Fix Camp can be seen on the shoulder of the hill below and to the right of the cairned triangulation station.

tal sextant angle). The plan was then to move the Balin Point station to Cape Meier which would extend cover to the area south-west of Signy Island without the necessity of moving the other slave station.

8. All these sites were reasonably accessible by boat. They all had a sheltered area on which to erect the living and equipment tents. The ground was hard, consisting mainly of broken shale with a growth of moss and lichens, but it seemed to provide the best anchor points for the mast and reasonable conductivity for the earth mat. In landing the gear the lightness of Hi-Fix equipment was found to be a tremendous advantage — no single unit was too heavy for one man to carry, although for a long distance it was better if a box was carried between two. The diesel-powered battery chargers that had been obtained were also quite light; the most difficult items to land were the 40-gallon drums of diesel oil and paraffin. All the slave stations were on the air within a day and a half of the first load being carried ashore.

Calibration

9. As the Hi-Fix equipment had never been used in the *John Biscoe* before a full calibration was carried out.

a) ***Ship's Electrical Centre***

Hydrodist equipment was used for this calibration. The remote instrument was set up close alongside the Hi-Fix mast at the slave station while the master instrument was operated from the upper bridge of the *John Biscoe* 34.80 metres ahead of and 0.70 metre to port of the Hi-Fix mast. Hydrodist readings and Hi-Fix readings (H.F. pattern only) were then taken simultaneously on eight evenly disposed relative bearings while the ship turned in a tight circle. Three separate sets of observations were taken as follows :

	Slave used	Distance	Dirn. of turn
Run one	Slave two	17 000 m	Starboard
Run two	Slave two	17 000 m	Port
Run three	Slave one	8 000 m	Port

Hydrodist ranges were converted to theoretical Hi-Fix readings by applying a mean met. factor to obtain spheroidal distance (slope and height corrections being insignificant) and by direct application of frequency used (1938 kc/s) and phase lag factor (see below) in reverse. Hi-Fix lanes thus derived were compared with counter readings and a set of distances in lane terms obtained for each relative bearing, which represented locking constant plus or minus distance to electrical centre. Locking constant was next eliminated and the residual distance to electrical centre converted into metres with the following results :

Rel. Bg. Slave	Run 1	Run 2	Run 3	Mean
1. Ahead	+ 37.9	+ 34.8	Missed	+ 36.1
2. Port Bow	+ 31.7	+ 27.1	+ 22.4	+ 27.1
3. Port Beam	+ 13.9	+ 1.5	— 2.3	+ 4.4
4. Port Quarter	— 17.0	— 19.3	— 25.5	— 20.6
5. Astern	— 33.3	— 35.6	— 33.3	— 34.1
6. Stbd. Quarter	— 26.3	— 29.4	— 20.9	— 25.5
7. Stbd. Beam	+ 10.0	— 4.6	+ 6.2	+ 3.9
8. Stbd. Bow	+ 24.0	+ 22.4	+ 22.4	+ 22.9
9. Ahead	+ 35.6	+ 36.3	Missed	(See 1)
Locking Constant (Lanes)	0.13	0.12	0.14	

These distances were then plotted as " starsight intercepts " from the Hydrodist instrument and yielded a position for the ship's electrical centre 1.1 metre to starboard of and 0.3 metre abaft the actual Hi-Fix mast (probable error ±2 metres). These results were considered to be satisfactory. For all practical purposes the positions of the Hi-Fix mast and

the ship's electrical centre could be taken as being one and the same. The scatter of the observations taken on the beam when compared with those taken on the other relative bearings is interesting and cannot at the moment be explained

b) ***Locking Constant***

Locking constant was obtained by steaming the *John Biscoe* round each slave station in turn at a fixed distance. A comparison was made between the theoretical lane derived from Hydrodist and the actual Hi-Fix reading. Hydrodist distances were converted as in (a) above and in addition the relative bearing of the slave station was observed each time and a correction applied for distance to electrical centre. The value of the locking constant for both the H.F. and L.F. patterns was obtained for approximately every 6° change of bearing for each slave over the arc of intended use. Results are tabulated below to demonstrate their consistency, the true bearing of the slave station being omitted :

	Slave One Dist. 10 500 m		Slave Two Site One Dist. 9 700 m		Slave Two Site Two Dist. 10 100 m	
	H.F.	L.F.	H.F.	L.F.	H.F.	L.F.
Values of locking constant for approx. every 6° of arc	0.36	0.26	0.12	0.20	0.17	0.19
	0.45	0.32	0.12	0.23	0.19	0.18
	0.36	0.29	0.16	0.16	0.22	0.21
	0.37	0.26	0.12	0.23	0.09	0.18
	0.33	0.25	0.10	0.23	0.18	0.18
	0.35	0.24	0.13	0.17	0.19	0.18
	0.28	0.26	0.19	0.32	0.20	0.18
	0.28	0.24	0.13	0.23	0.21	0.17
	0.29	0.20	0.14	0.22	0.20	0.13
	0.33	0.28			0.15	0.17
	0.27	0.20			0.16	0.16
	0.34	0.27				
	0.25	0.23				
Mean	0.32	0.25	0.13	0.21	0.18	0.18

As the slave stations were all sited on even distance back from the high waterline over the arcs of intended use this result was much as expected. The mean value for the locking constant was therefore employed at each slave station, the value being fed in reverse to the receiver/slave control unit at the appropriate slave station.

c) ***Phase Lag Factor***

It has been decided in the Surveying Service of the Royal Navy to employ as standard for all such radio position fixing aids the velocity of radio waves in vacuo (299 776 km/sec). The whole correction necessary to rectify this to an observed velocity of radio waves is then regarded as

phase lag factor. In practice there is little difference between this method and employing varying velocities of radio waves outright but it has the merit of making phase lag factor a definable entity and phase lag factors under different conditions are directly comparable. The value of phase lag factor used was 0.999867 (which is equivalent to employing a velocity of radio waves of 299 736 km/sec). It should be noted that the sea was not frozen at the time of the survey and icebergs scattered over the area provided the only variation from a direct sea-water path. An attempt was made to test this value of the phase lag factor. This was done by determining the locking constant at different ranges from a slave station. Unfortunately the test had to be carried out in two parts on different occasions and using the same slave but at a different site. The results were as follows :

	Distance from slave in HF lanes	HF locking constant	LF locking constant
Part 1	260	0.37	0.21
	250	0.49	0.12
	240	0.37	0.25
	230	0.36	0.10
	220	0.34	0.14
	210	0.35	0.21
	200	0.32	0.22
	190	0.32	0.19
	180	0.27	0.20
	170	0.33	0.18
	160	0.30	0.17
Part 2	130	0.28	0.17
	121	0.23	0.18
	111	0.19	0.17
	101	0.16	0.15
	91	0.19	0.15
	81	0.21	0.14
	71	0.19	0.14
	61	0.22	0.17
	51	0.14	0.12
	41	0.17	0.26

Examination of these results is rather inconclusive. There is a marked jump in the HF locking constant values between Part 1 and Part 2 of the test, but as this was not reflected in the LF locking constant values it is suspected that this was due to some cause other than phase lag factor. Ignoring this jump there is a slight trend indicating that the value of the assumed phase lag factor (and therefore the value of the comparable speed of radio waves) was too high. Time did not permit a further test. The above results were sufficient to indicate that the phase lag factor if incorrect would not be sufficiently so to introduce errors on the scale of the survey (1/50 000) at the range that Hi-Fix was going to be used.

d) ***Pattern Stability***

Unless a vessel can secure alongside there would seem to be no satisfactory way of testing the pattern stability. Needless to say this was not possible in the South Orkney Islands. The absence of any tendency for the counters to hunt, the smooth transition of the counters from movement in one direction to movement in the other and the ability they showed to detect even the roll of the ship gave confidence that there were no short period fluctuations in pattern stability.

e) ***Range***

The survey area was all within a short range (30 miles) of the slave stations and therefore no great demands were made on the equipment in this respect. On one occasion lock was maintained out to nearly sixty miles. The following typical signal strength readings were obtained :

Distance	Reading of signal strength meter
19 miles	7.2
37 1/2 miles	4.0
50 miles	1.6 (partial land path)

Mode of operation

10. In the long Antarctic summer days 24 hours per day operation would have been feasible if men and equipment could have stood the strain. In the event an average of about 15 hours per day was worked and the ship usually anchored close to one of the slave stations overnight. The ship's master transmitter was never switched off and at the slave stations the receiver/slave control unit was left switched on (on battery power only). The slave stations therefore remained continuously locked on and starting off in the morning merely consisted of starting up the diesel generator and switching on the transmitter. On board the *John Biscoe* the counters had to be reset from a horizontal sextant angle fix. At the inshore ends of the lines this presented no problem unless there was an early morning mist. The merit of this partial switch off was that it gave some scope for preventing maintenance — whether this advantage outweighed the disadvantage of having to reset the counters each morning was difficult to decide. In a later survey round the clock operation came to be favoured, but there the difficulty of resetting the counters was much greater.

Plotting

11. Chartroom and chart table space is at a premium on board the *John Biscoe*. Instead of the familiar mounted sounding board a Permatrace

sheet was used to plot the ship's position. Position circles representing every tenth lane were drawn on the back of the Permatrace sheet. Because of the size of the sheet this had to be done on the deck of the bridge and the manœuvring of the scale, the inks and the large beam compass is remembered as being the most difficult part of the survey. The position circles were then labelled and lacquered over. Plotting was done on the front of the sheet which was kept rolled up apart from the area in use. A piece of round perspex (from an electric torch) was engraved with concentric circles at one lane intervals and a bevelled-edged hole sufficient to admit a sharp pencil was cut in its centre. This homemade piece of equipment made plotting the lanes and fractions of a lane simplicity itself.

Sounding operations

12. Sounding began as soon as the calibration was completed. Whenever possible the ship steamed along the position circles radiated from one slave station or the other — a procedure familiar to all users of this and similar systems. The continuous check that the vessel was "on line" made ship handling easy and the ship's officers who had no previous experience of handling a ship in this way were soon very proficient. Alterations of course to avoid small floating pieces of ice presented no difficulty — extra fixes were taken to plot the "dog leg" and the correct line was easily regained. A helmsman's indicator had been provided with the aid of which it had been hoped that the helmsman would have been able to follow a position circle round without any courses being ordered by the officer of the watch. The instrument proved to be too sensitive — as little as 8 metres off line gave a dramatic indication and because the Hi-Fix mast was well abaft the ship's turning point the effect of corrective helm was to make the reading initially worse. The indicator would probably work excellently in a boat if the Hi-Fix mast was above the craft's turning point, but on board the *John Biscoe* its use was abandoned in favour of conning the ship from the reading of the counters. Except in poor visibility or when in shallow water or among the ice it was perfectly feasible for the ship to steam at full speed. An average of over a hundred gainful miles of sounding each day was maintained.

Narrative

13. The area east of Signy Island was sounded out first using the Saunders Point and Balin Point Hi-Fix sites for the slave stations. Lines were run at intervals of 0.2 inch on the paper (about 280 yards on the earth) but when even depths of over 100 fathoms were encountered double spacing was used. A 100-fathom trench was revealed stretching up the east coast of Signy Island right into the narrow channel between Signy Island and

Coronation Island. Quite deep water was encountered close into Coronation Island and the ship could approach to within 1 1/2 miles without danger. The bottom topography was found to be very even when compared with the rugged features of Coronation Island.

14. A large iceberg covering an area of about 25 square miles unfortunately occupied part of this area. It was aground, but not very firmly so and it moved slowly about with the tide and wind. One hundred feet high, it must have had a draft of more than 60 fathoms, although this depth could not necessarily be guaranteed along its northern edge where it might have been resting against a shoal or rock pinnacle. Soundings were taken to seaward of this iceberg. A fall off in signal strength was observable when the ship was close to the iceberg on the side removed from the slaves, but lock was not lost. Undoubtedly some errors were introduced when this large area of ice was interposed between the ship and the slaves, and close into the iceberg boundary effects might have introduced larger errors. Because of its enormous height there could be no check on the magnitude of these errors, but it is thought unlikely that they would be more than just plottable. As the depth of the water was everywhere over 100 fathoms they were accepted. With incredible perversity the iceberg remained until the last day of the survey when, too late for the gap to be filled, it was seen to blow off and vanish away to the south-eastward.

15. The inshore area was sounded out by the surveying boat from its base on Signy Island. There were sufficient marks here for horizontal sextant angles to be used. And on one fine day the area of the inter-slave baseline, where there was no fix from Hi-Fix, was sounded out by the ship using visual methods. The link up between the boat's work and the ship's was good and the repeatibility of Hi-Fix was amply demonstrated when shallow soundings were revisited for examination. Some off-lying rocks south of the Coronation Island were fixed from the ship using the ship's Hi-Fix derived position and a single horizontal sextant angle to provide an intersecting ray. Several such observations combined with a theodolite observation or two from a main triangulation station gave a good cut in every case and also helped to build up confidence in the accuracy of the Hi-Fix equipment.

16. After a week of steady sounding the area east of Signy Island was completed. Orders were given to dismantle the Hi-Fix slave station at Balin Point ready for it to be moved to Cape Meier. This day was used to sound out an area south of Signy Island (and to seaward of the boat's area) using the Hi-Fix slave station at Saunders Point to provide one position line and a sextant-observed visual cut-off angle to marks on the south coast of Signy Island to provide the other. This avoided the necessity of using the other slave station when, from either site, its transmissions would have been subject to land path effects.

17. The Cape Meier slave station could not be established on the summit of the peninsula because the thaw of the perma-frost had made

the ground so soft that the Hi-Fix mast stakes would not hold. A site was therefore chosen on a shingle beach a little above the high waterline. Once the local inhabitants — family of elephant seals — had been moved on, the site proved to be perfectly satisfactory. It was calibrated for locking constant as previously described.

18. The final area south-west of Signy Island proved to be free of dangers and very even in its bottom contours. Two formidable looking charted rocks — Whale Rock and Cachalot Rock — proved to be non-existent. First put on the chart fifty years ago and, no doubt, carefully avoided ever since by two generations of Antartic mariners, it would seem liekly that the Captain who reported them actually mistook growlers (small pieces of very hard black ice which often break viciously) for rocks.

19. During this final period the weather deteriorated. There were some days of low visibility when the ship was delayed in obtaining her initial fix to set the counters, but once they were set it was very satisfying to be sounding on through the mist when in the days before Hi-Fix she would have had to remain idly at anchor. High winds, however, were more serious. At the slave stations the shore parties had to keep a firm eye on the tents and on the Hi-Fix masts. The slave station at Saunders Point had the worst of it here — a devastating katabatic wind would suddenly sweep down the glacier from the centre of Coronation Island. One tent was torn to shreds and twice the Hi-Fix mast was brought down — once when a guy pulled out and once when the mast literally folded up before the force of the wind. The resourcefulness of the Decca Company's engineers in keeping their equipment operating in such difficult conditions was most commendable — even the ruptured mast was quickly repaired using sections from the lifting arm (provided for mast erection).

20. After twenty-nine days in the area the R.R.S. *John Biscoe* had to sail south to relieve the southern bases of the British Antarctic Survey. On 9th February, 1965, the survey was therefore broken off and all men and equipment safely recovered.

Statistics

21. It is interesting to analyse the results obtained using Hi-Fix. It should be noted that the slave sations were unfavourably sited and that a better ratio of working days to days available would have been achieved if it had not been necessary to shift one slave station in the middle of the survey. Calibration could also have been curtailed if it had not been necessary to test as a new installation.

R.R.S. *John Biscoe* available	29 days
Erecting, setting to work, fixing, calibration, shifting to new site, dismantling	12 days
Days lost due to bad weather or equipment failure	3 days

Working days	14 days
Miles of soundings run (not including soundings obtained by sounding boat)	1 500 miles
Estimate of the number of miles of soundings likely to have been run by the ship in the 29 days if only visual methods had been available	500 miles

The figures for Hi-Fix serviceability were excellent:

Total number of hours Hi-Fix was required	303 hours
Total number of hours Hi-Fix was serviceable	294 hours
Ratio	97 %

From a user's point of view these present Hi-Fix in a rather too favourable light — a momentary failure can waste hours of time if the ship has to steam many miles from the outer ends of her lines to a place where she can get a good visual fix to reset her counters. But if the difficult conditions, the absence of workshop facilities, the impossibility of obtaining any extra spares beyond those initially supplied are taken into account, Hi-Fix must obviously be considered to have passed a rigorous test extremely well.

Hi-Fix equipment

22. The general functioning of the equipment was most satisfactory. Its high serviceability has already been referred to. Due to a certain weakness in the relays there was a tendency for the alarm lamps to flash rather frequently and all spare relays were used up during the survey. (It is believed that relays of an improved standard are now being used). However, in spite of the rather pessimistic view expressed by these recurrent flashes, actual lane slip occured only twice and was noticed and corrected on both occasions.

23. The unsuitability of the helmsman's indicator for use in the R.R.S. *John Biscoe* has already been commented on. Rather more serious was the failure of the lane identification display unit to provide positive indication of lane. The lane identification system, it will be remembered, works on the principle of duplicating the main (or high frequency) pattern with a (low frequency) pattern of nine-tenths that frequency. Subtracting the low frequency pattern from the high frequency pattern (done automatically in the lane identification display unit) then provides indication of H.F. lane and tenths of a lane within a ten lane block. In practice the display unit gave a variable indication sometimes as much as 1.5 lanes too high or too low — the error seemed to vary with the distance from and the relative bearing of the slave station. Several theories have been advanced as to why this error should have occurred, but time did not allow a test to be carried out that would have resolved the matter. The effect of the error was to inhibit the use of lane identification in setting up the

FIG. 4. — View of the Hi-Fix mast and equipment tents on Balin Point, Signy Island.

counters — the surveyor was not satisfied until visual fixes had located his position within the lane rather than within the ten lane block. Much of the value of lane identification was therefore lost.

Summary of experience in Antarctic use

24. Hi-Fix has proved itself to be well suited to Antarctic operation. In most of the Antarctic suitable slave sites are few and an equipment that occupies a small area and makes use of a light easily erected aerial mast is to be preferred. The stout, but lightweight boxes into which the dismantled Hi-Fix slave station is crated were excellent and made light work of even the most difficult landings. One box fell into the sea but was recovered after about half a minute completely undamaged.

25. One lightweight mast collapsed in a wind that was estimated as being 85 knots. A stronger and heavier mast is available but this would need stronger guys and — most difficult of all — firmer anchors. It is intended to persist with the light-weight mast. Spare mast sections will be taken and sites influenced by katabatic winds avoided where possible. The

problem of anchoring the guys is not always best solved by stakes — heavy weights perhaps in the form of gabions filled with stones might well prove to be the best solution.

26. The experience of Canadian hydrographic surveyors in the Arctic (Reference 1) has been read with interest. Probably because helicopter support is seldom available in the Antarctic the question of unmanned operation of the slave station has not been seriously considered. Numerous minor defects were remedied by the slave station crews. A fall of snow would affect aerial tuning and this would be remedied by the men on the spot. All in all, manning the slave stations saved time in the long run and safeguarded the equipment against serious damage (an important factor when working completely away from any base support).

27. Very low temperatures (below 0 °C) were not encountered. Lead acid batteries functioned perfectly adequately and good service was given by diesel driven battery chargers. Three of these were allocated to each slave station which allowed one battery charger to be serviced while one was on load and the other at stand by. Battery chargers were run in the open, or behind a shelter of crates, and no problems of overheating were therefore encountered. Larger fuel tanks would have been a convenience as the battery chargers had to be refuelled every four or five hours.

28. The three-man Arctic tent which was used for both men and equipment proved to be excellent for its purpose. Only during an unusual period of heavy rain was any disadvantage in its use exposed. However, anything more elaborate needs a very carefully prepared site and would certainly be much heavier — it would seem to be a case of the simplest way being the best.

29. The ideal communications system would provide for constant loud-speaker watch at the slave stations (at a low cost in electric power) together with two-way communication direct from the equipment at the slave station to the master reeciver on the bridge of the survey ship right out to the limit of the survey area. Such a set was not available in the R.R.S. *John Biscoe* last year and quite a lot of time was wasted waiting for routines. The requirement is now recognized and new equipment has been provided this year.

Conclusions

30. Hi-Fix has proved its worth in the Antarctic. In the first season the R.N. Antarctic Survey Party embarked in the R.R.S. *John Biscoe* has been able to do about three times the work that would have been possible without it. Certain shortcomings require attention — notably the performance of the lane identification system was not satisfactory for some reason. The special problems of Antarctic operation are:

(a) The difficulty of maintenance with limited resources and space;

(b) The extra difficulties attendant on slave station selection in a part of the world where suitable places are few and far between.

Useful experience in both these particulars and in other problems was gained in the South Orkney Islands survey in 1965.

Reference

[1] R. M. EATON. — Experience with Hi-Fix Hyperbolic in the Canadian Arctic. *Supplement to the International Hydrographic Review*, volume 6, September 1965.