MOBILE DECCA CHAIN TESTS IN ZONE FROM PENMARC'H TO BELLE-ILE

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(Extracted from Report on the test carried out by the Service Hydrographique of the French Navy)

I. — SCOPE AND OBJECTIVE OF TESTS

The main purpose of the trials ordered was to investigate the stability of the lattice produced by the chain and to determine its ability, apart from any visual observation, to provide accurate tracking for a group of sweepers up to about 30 miles from the coast.

Systematic observations were therefore directed towards first ascertaining the *stability* of the net, then its *reliability* — that is, the possibility of relocating an identical position on the bottom by Decca alone —, and finally its *accuracy*, or the linking up of Decca readings with geographical positions.

The range of requirements was thus largely different from those motivating the suppliers of the chain, which according to Decca terminology was intermediate between the mobile and light Decca chains and was intended to be used for experimental purposes by the French Army Air Force. According to contract specifications, the chain was required primarily to have a relatively rough mean stability of 15/100 of a lane, a long range (400 km.), and a robustness tested by 1000 hours of continuous operation. The effort to attain a degree of stability (and especially of accuracy) on the order of a few hundredths of a lane, with relatively crude receiving and monitoring equipment and a limited unskilled staff, in an area noted for its harsh climate, pointed the way from the very outset towards an attempt at solving entirely new problems of research through the working-out of a rational operating technique adapted to the numerous factors causing errors.

In spite of numerous difficulties, due to the frequent breaking down of accessory equipment and to instrumental imperfections, some purpose was served by these investigations. The tests made it possible, while information was used that appeared unreliable, to arrive at causes and remedies inherent to the errors involved, and were conducive to often exceptionally reliable quality of performance, as well as encouraging possibilities in the conduct of sweeping operations and fully adequate approximations in linking Decca with geographical co-ordinates. As a result, consideration might well be given to Decca as a simple and rapid method for determining positions of deep-sea soundings. As a matter of fact, in spite of one of several inadequate factors, consisting of the Mark IV Marine receiver, an already obsolete type, the 60-metre degree of accuracy hoped for at a range of 30 miles was not, on the average, lower than 90 metres at that distance, and within visual range of landmarks proved to be better than 30 metres.

II. — LOCATION OF CHAIN

a) Transmitters.

A vast number of wave propagation problems that would have proved difficult to cope with in practice were avoided at the outset through careful choice of the location and spacing of the transmitters, in such a way that they would be able to operate at peak radio-electrical and pattern efficiency.

The stations, consisting of a Master-station near the old Pouldu semaphore, a Red Slave-station near Lesconil semaphore and Green Slave-station near Taillefer semaphore at Belle-Ile (1), were sited as follows:

(1) Base-line apertures were approximately 120° wide;

(2) Stations were equidistant from one another (about 50 km.);

(3) In the majority of positions covered by the pattern, travel overland was reduced to a minimum.

It was therefore possible to adopt a single propagation speed, and for this reason a large number of tests to obtain correction for overland travel could be avoided, an operation that would have required difficult and delicate measurements of the local propagation speed. The only site involving passage overland on the order of 5 or 6 km. was that of Belle-Ile, and each time that this took place, anomalies that were appreciable in extent were observed.

The numerous conditions to which the siting was subjected (such as the proximity of an arsenal, distance from tension lines and public and accessible land) made it impossible to effect a strict evaluation of the quality of the ground, which plays such an important part where the coefficient of radiated power is concerned. In spite of the doubling of the groundwire system, therefore, whereas antenna intensity at Lesconil exceeded 10 amperes, at Taillefer, on rocky ground, it hardly went beyond 7.5 amperes.

In the future, this factor might well be taken into account and the earthing increased in ground of poor conductivity.

b) Monitor.

The Island of Groix offered almost ideal possibilities for the siting of a monitor station, used for the continuous measurement of the stability of the system. It was set up near Beg Melen semaphore, and at the cost of a slight constant distance to be crossed over land on the green lattice, measured hundredths of a phase having a value of 5 metres on green and approximately 8 metres on red.

III. — BRIEF ACCOUNT OF TRIALS

Site investigation and selection took place on July 25, 26, and 27, 1950.

During these investigations:

(1) Stability was checked by minute-by-minute readings;

(*a*) At Beg Melen (Groix) Monitor station, whose Mark IV Air type of receiver was more sensitive than the ship-borne receivers;

(*b*) On board at least one sweeper at fixed anchorage point or Keroman wharf.

(2) Checks for reliability were made along a hyperbola in lanes extending beyond 10 miles, and whenever a buoy was encountered at a point on the hyperbola, to the ends of these lanes.

(3) Pattern adjustment was checked at over 90 stations by surveying circle, whenever visibility permitted, at distances averaging 10 miles offshore.

(4) Pratice in following a hyperbolic course over the bottom took place on each vessel at cruising speed (10 to 11 knots).

(5) Sweeping of hyperbolic rectangles was attempted by all three sweepers in formation, and positions checked from buoys at the end of each run.

(6) A hyperbolic tracking test was made while operating a drag in the water.

(7) Checks for night stability and for types of errors due to propagation at night were made by the three vessels at three points in the system.

(8) A jamming test was made by the Kerneval station during the day-time.

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(1) Sie Pattern Specifications: Annex II.

IV. — TECHNICAL INCIDENTS

The installing of both a Diesel and petrol unit at Le Pouldu and Taillefer finally solved the question of mechanical and electrical breakdowns. At Lesconil on the other hand, the use of the local current supply and a voltage-regulator ensured perfect smoothness of operation towards the last.

Radio-electrical trouble did not, however, occur too frequently, and fortunately had no serious results. It consisted of the following :

Voltage losses upon reception at Monitor station: battery insufficiently charged.

Two breakdowns of reference oscillator of Beg Melen receivers.

Throwing out of line of automatic phase controls at slave stations.

V. — PHASE CONTROL

Phase control is identical at both Red and Green slave stations. It consists, roughly, on the one hand of an automatic phase corrector of an electronic type that operates, within narrow limits, following a very slight dephasing of master-slave transmission.

Beyond these limits, on the other hand, it consists of a manual control operated through the agency of a goniometer manipulated by the station supervisor, who alone is able to bring the oscillations back within limits subject to automatic control.

Proper operation therefore requires continuous supervision of the indicator to prevent the system from « shifting » outside the range of automatic control, and precise regulation of the automatic control at a stable point of operation.

This situation could be remedied either by using a *double* phase control system or a single highly accurate control system of tested stability.

VI. — OPERATIONAL GRIDS

The construction of urgently needed operational documents by the *Service Hydrographique* is dependent upon the availability of extensive facilities, a relatively large and experienced staff, and a certain amount of time.

Delays were comparatively small, considering the newness of the problem, for which there is no universally adopted solution abroad. Documents supplied by the *Service Hydrographique* were of two types:

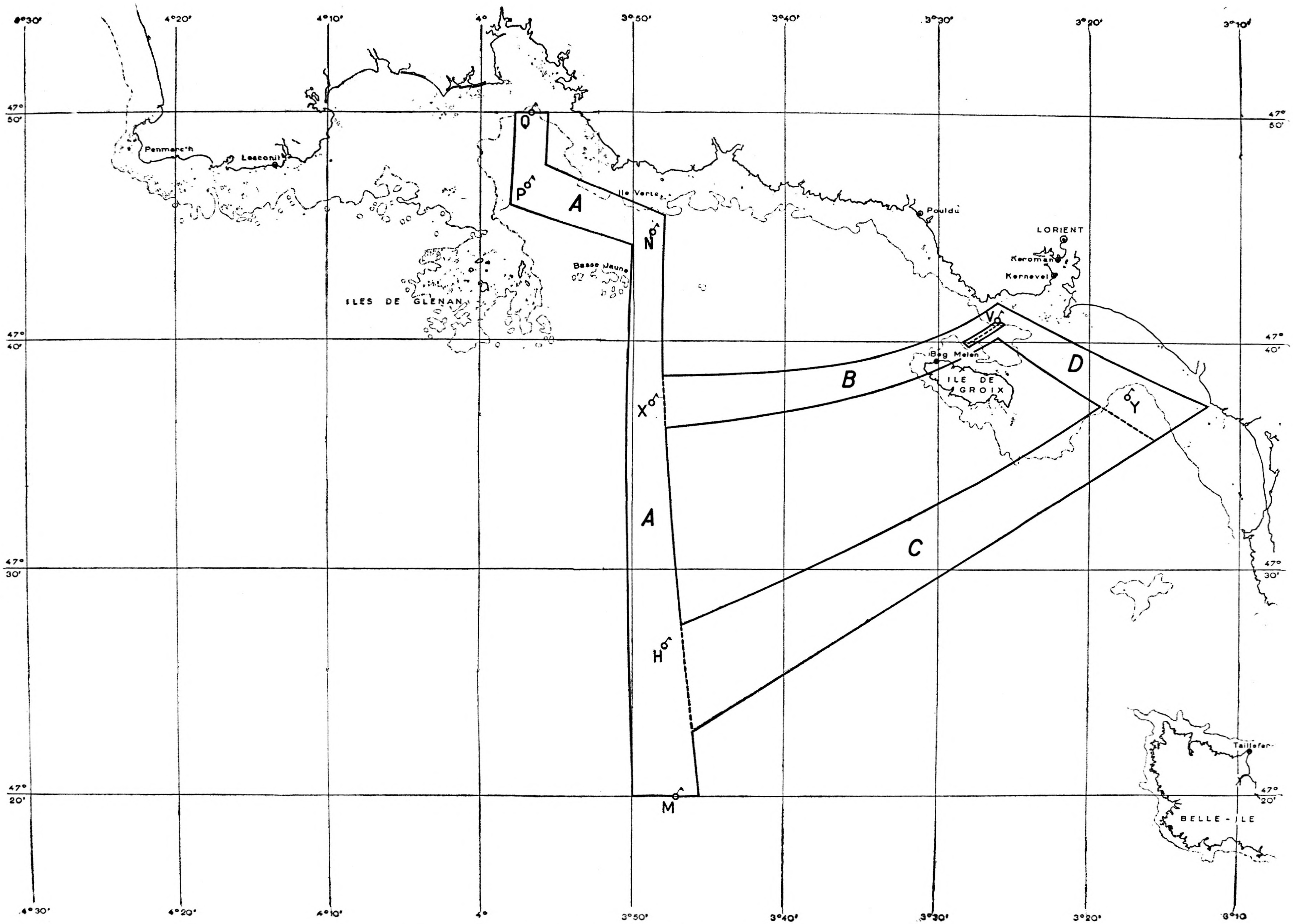
(*a*) A tracing of a projection on the scale of 1:100 000 of the Penmarc'h-Belle-Ile area (Chart N° 5405, scale 1:121 000) overprinted with hyperbolae of the two systems, plotted as distance differences as plane hyperbolae on a flat Earth. Neglecting curvature of the Earth, the danger of errors in plotting was therefore less than 6 metres at a distance of 30 miles.

(*b*) A series of 6 tracings on the scale of 1:25 000 representing sections of the three drag-lanes A, B, C within zones of this area with sufficient width, overprinted with phase hyperbolae plotted by means directly computed points.

At every point on these latter projections, a distance of 45 metres corresponds to an average linear distance of 1.8 mm. with a reading of one-tenth of a phase on the base-line and 5 hundredths of a phase at any range.

The speed of propagation adopted after consulting with Decca Company engineers in London was 299,700 km. per second.

Results obtained showed that this single estimate was fairly accurate as long as no passage over land was involved; some definite differences became apparent, however, at certain points located near land (specifically, observations of the *Basilic* and *Dahlia* at anchorages of Ile Verte, Groix (Port Tudy) and Penfret).



Essais d'une chaîne transportable Decca dans la zone de Penmarc'h à Belle-Ile.

Movable Decca chain tests in zone from Penmarc'h to Belle-Ile.

Note.

In order that additional calculation might be avoided, points in the system on the scale of 1:25 000 were computed in four symmetrical quadrants, which ended up by involving the existence of a symmetrical remainder at both of the base-lines.

This method, although at variance with British technique and usual practice, the latter consisting in the use of an asymmetrical diagram starting at phase Zero from the master-station, actually has no incdnvenient aspects as regulation of the master transmitter enables accurate adjustment of the system at will.

VII. — OPERATIONAL TESTS

(1) *Stability.* — This essential quality of the Decca chain was intensively and methodically investigated before any practical application took place. Indicator observations were made at one-minue intervals at various fixed points during an entire day and night period of operation of both lattices. The old-type Mark IV Marine ship-borne receivers were responsible for a certain number of errors, bringing reading discrepancies up to about 3 hundredths — a considerable amount in view of the accuracy desired, and substantially influencing the final uncertainty of Decca fixes.

The Mark IV Air type of receiver at the Groix monitor station, powered by 25-volt direct current, was more sensitive than the ship-borne receivers, which were twice as sluggish as the former.

Observations were subsequently analyzed and converted into a large number of daily curves, which upon examination revealed the following characteristics:

(1) The existence during the day-time of a slow drift in average readings, in accordance with no well-defined rule, although of roughly sinusoidal aspect, and consequent upon rapid fluctuations lasting between an hour and a half and two hours, the latter depending upon weather conditions and the time taken by the receivers to warm up once started. This drift is compensated by corrections applied to the pattern.

(2) Deviations of great amplitude, from 30 to 40 hundredths, occurring when the range of the automatic phase control is exceeded and manual control does not immediately intervene. This need not happen if continuous and reliable supervision prevails.

(3) Random deviations due to rain or dampness that may reach 20 hundredths and produce drift of the automatic control. They may be avoided by drying out the insulators and through study of a new tpe of indented insulator and of a screening system to protect the aerial insulators and mast-steps.

(4) Random and fluctuating deviations due to wind-action. These are non-existent during fine weather and of slight amplitude, but nevertheless affect accuracy of measurement. They are reduced if there is maximum tightening of aerials on masts capable of carrying loads corresponding to the weight of the aerial equipment (about 250 kg.) and of resisting the considerable wind-pressure.

(5) Random deviations due to uncertainty of readings, to the absence or poor quality of the reference control, which consists in a periodical checking of Zero by connecting up a referdnce oscillator, located within the receivers, which substitutes a Zero phase-difference for the one supplied by the receivers.

To sum up, if causes 2,3, 4 and 5 are considered as having been eliminated and if drift is assumed as being compensated to within one-hundredth, either by means of corrections of the monitor station to the Slave phase-controls or those applied to readings, average stability on a dry, calm, windless and rainless day, under conditions of regular operation and careful supervision, was as follows:

$\pm$ 2/100 for 90 % of Red readings

$\pm$ 2/100 for 88 % of Green readings

(2) *Receiver Operation.* — It may be well to reconsider the vital subject of the receivers, since their quality may be such as to modify the evidence of stability. The results enumerated above are in reference to the Mark IV Air

receiver at the monitor station, which was of greater sensitivity than the ship-borne receivers and supplied by a 24-volt battery at an appreciably constant voltage rate.

The ships were equipped with four Mark IV Marine receivers supplied with a current of 110 volts. These receivers are subject to causes of errors owing to the unevenness of the power supply and irregularity of the local reference oscillator. The later Mark V and VI models are relatively immune to such errors and the Survey receiver is altogether rid of them. From the point of view of stability, the uncertainty of Mark IV readings is in a way counterbalanced by inertia. Two out of the four available sets gave excellent results on the *Dahlia* and *Basilic*, but on the *Armoise*, which was not equipped until after October 21, the receiver had to be replaced, and the new one could not be as effectively used as those on the other vessels. It should be pointed out that there were duplicate sets of receivers on the ships as well as at the monitor station; each set, however, was tuned to a slightly different frequency band — bands 7 and 9 — as the chain was equipped to operate on two frequencies. This may present interesting possibilities in certain cases, but note should be taken of the fact that in these circumstances two operational patterns must be prepared.

Trials carried out at Lorient involved the use of Band 9 only, specifications of which are appended hereto.

(3) *Technique of Pattern Adjustment*

This consists in first siting the pattern with reference to the one plotted on the chart projection, and in then making occasional corrections necessitated by drift.

Initial adjustment operations consisted in bisecting the base-line extensions at right angles beyond indirect field range by a ship on one side and a truck equipped with a receiver on the other. Minute-by-minute readings pass through a maximum figure that should correspond to the pre-computed value of the grid on the base-line.

Several technical difficulties interfered with the tests — checked by means of carefully plotted curves — and three attempts had to be made at each base: off Penmarc'h and southeast of Belle-Ile.

After approximate adjustment of the pattern had been checked in this way, observations checked by surveying reflecting circle enabled determination of the residual corrections to be applied through accurate phase-controlling at the slave stations in order to obtain an absolute fit.

Incidentally, it should be pointed out that the enforced use of a single lattice during periods when the other was not working revealed that corrections were very different when both were in operation.

The continuous drift of readings at a fixed point and shifting of the system as a whole outside the range of automatic control necessarily involve re-setting the pattern at intervals in the correct (or geographical) position, either periodically or by accounting for lack of proper adjustment at each reading.

The usual method, which has been satisfactorily tested by British, Danish and Swedish experiments with superior equipment, consists in the transmission to the slave stations of the applicable phase-control corrections.

This procedure, which should only occur 5 or 6 times a day, was not considered feasible after the first few tests for the following reasons:

— Inexperience of slave station personnel;

— Personnel untrained for shift correction;

— Inaccuracy of phase control, and

— Inconvenient operation of adjustment condenser dial, its size and graduations making accurate manipulation difficult.

The only accurate method then resorted to consisted in requesting the monitor station at each adequate reading to provide five fairly concurrent readings so that the average applicable correction to the ship's reading could be derived.

Justification for this procedure was the unreliability of phase control operation, leaving a substantial correction remainder warranting a reading correction in every instance.

Intensive use of the wireless telephone was a necessary consequence. It should of course be stressed that efficient operation of a chain better adapted to the desired accuracy than the one available can only be conceived as involving direct application to the system of corrections detected by the monitor station. The latter alone makes the decisions affecting the pattern situation.

If under these conditions stability is good and corrections are normally applied to the pattern, the user afield need not worry about any residual error of a few hundredths that may be left over, and operation is relatively silent and unobtrusive.

Minute analysis of readings at Beg Melen Monitor Station on a day characterized by dry, calm weather showed that application of the correction five times daily would have brought the lattice back into its proper position to within an average of two hundredths.

(4) *Instrumental error.* — Comparison of corrected Decca readings and geographical positions revealed a discrepancy inherent to the receiver and receiver carrier (in this case, the ship). Ascertained as being averagely constant, the error long resisted accurate determination. Following upon various other uncertainties, of which that of the Mark IV Marine receiver readings was by no means the least in importance, it continued to be affected by a fluctuation equal to that of final error, or averaging 5 to 6 hundredths.

This error, called « instrumental » for convenience, differs with each receiver, receiver carrier, and the current supply in each particular instance.

Comparisons made between the three sweepers at sea showed slight differences. The metallic mass of the carrier has an effect, and it was noticed that readings were considerably off when the ship was moored at the Keroman berth under the cranes of a floating dock. A ship passing at less than fifty metres is sufficient to cause a marked deviation of the Decometer needles.

The receivers were connected to the ship's mains, and in spite of supervision were subjected to sudden power variations causing stray phase differences easily amounting to as much as 10 hundredths.

It finally became possible to obtain the mean value of this instrumental error by making numerous observations at various points, where the lane selected for measurement purposes was of sufficient width to produce only slight differences in hundredths of a phase in the case of considerable metrical errors. The reverse is true when testing for accuracy.

Mean values were — 10 and — 14 hundredths on Green and Red for the *Dalhia,* — 9 and — 15 for the *Basilic,* and about — 12 and — 17 for the *Armoise.*

(5) *Accuracy tests.* — This characteristic involves connection with the land. Readings corrected for pattern adjustment and instrumental error are then compared with the Decca co-ordinate position obtained with the surveying circle.

Observations were carried out at various points in the lanes marked with buoys, either at anchorage or at buoys for this special purpose. They involved more than fifty ship stations.

The final average discrepancy deduced from these observations amounted to between $\pm$ 5 and $\pm$ 6 hundredths.

Accurate distance measurements, granting correctness of the hydrographic position, depended upon the width of the lane at the point under consideration.

If the approximate value of a hundredth of a lane is admitted as varying between 5 metres on the base-line and 15 metres under unfavourable conditions, the metrical error varied between 25 and 90 metres.

Accuracy tests were on the whole satisfactory provided no passage of the waves over land was involved. Near Groix or the Glénans Islands, in shelter of land, a constant error of 20 one-hundredths showed up in the system, affected by travel over adjacent land.

VIII. — TESTS FOR COURSE MAINTENANCE AND RELIABILITY

Trials in this field were the most encouraging, and often remarkable.

(1) *Maintaining the Course.* — The new aspect of this problem is that the ship is compelled to follow a hyperbolical course over the ground in spite of wind

and current. The difficulty lies in the handling of the rudder, but the ends served make the task well worthwhile. The ship moves with a certain amount of drift and the inexperienced helmsman in the beginning is often confused in the process of trying to keep the Decometer needle on a given graduation. It would appear necessary at the outset to have the officer on watch bring the vessel onto the hyperbola required and then give the man at the wheel the mean course. As soon as the latter has figured out the proper direction of his response in order to get back to the correct reading — a direction that is often the reverse of the compass direction — he can generally be left to his own devices.

A second Decometer placed on the bridge and within access of the officer on watch would be a useful adjunct in checking the course.

Checks were made by recording readings minute by minute on the grid. It was observed that average yaw is much slighter than when steering by compass.

(2) *Reliability Tests.* — The system was tested for reliability several times by anchoring a buoy with a mine-sweeper on a hyperbola 10 or even 20 miles away from another sweeper. The latter was then supplied with the Decca co-ordinates of the buoy.

90 % of the time the vessel fell in with the buoy, which it crossed at an average distance of 20 metres. The longer distances prevailling in other cases can be explained by the drifting of the buoy around its moorings at depths reaching from 30 to 100 metres.

Two ships travelling along the same hyperbola made *rendez-vous* tests at the end of Lane A, at Points M or H, located approximately 25 miles away from the base-lines. Buoys were anchored at a depth of 105 metres at Point M 25 metres apart on Red and 60 metres on Green.

Instances of lane-slipping occurring during search for a buoy should however be mentioned, although they could be accounted for through improper operation of the reference oscillator, sudden power jumps, or brief interruptions in transmission.

It should be emphasized that under poor visibility conditions (such as during sweeping operations at night or in fog) occurrences of this kind are of a serious nature. Lane-slipping caused by faulty manipulation of the reference oscillator can be avoided if care is taken to note the reading prior to this operation. Power jumps in the receiver must also be avoided.

There is no remedy for temporary failure of the system, as dead reckoning is of no great help in an area where the hyperbolae are close together.

(3) *Effect of sweeping equipment.* — The operation of the magnetic sweep in the water had no appreciable effect on either the readings or the difference observed between the Decca and geographical positions.

(4) *Formation sweeping test.*

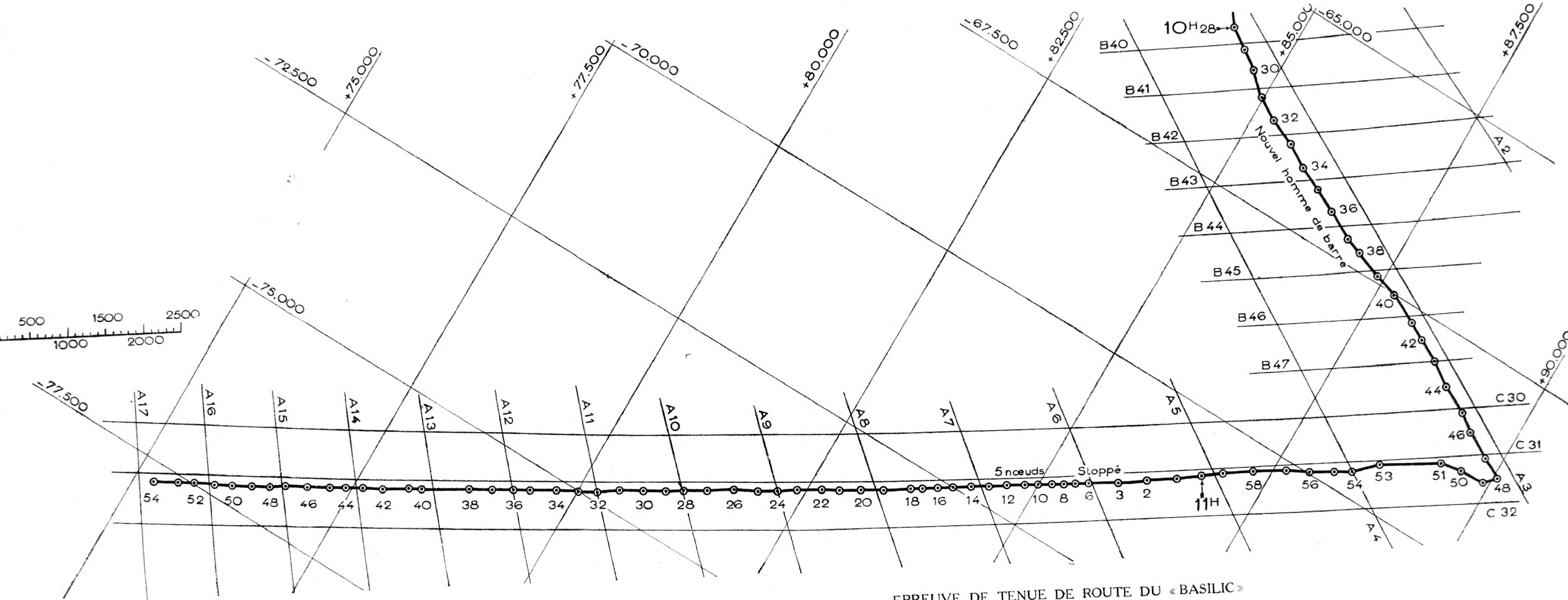
Each of the sweepers, first travelling abreast and then in R formation, followed a pre-computed hyperbola in such a way as to maintain a distance of 250 yards, checked at definite intervals by micrometer. This 250-yard spread had to correspond to a reading difference of 38 hundredths in the B 30 Green lane followed by the *Basilic*. Readings taken at two-minute intervals were as follows:

1250 hours	245 yards	Difference: 36 hundredths
1252 »	220 »	» 30 »
1255 »	275 »	» 42 »
1257 »	245 »	» 35 »
1308 »	280 »	» 36 »
1310 »	310 »	» 52 »

These differences show a remarkable degree of sensitivity in that distances of 5 yards are shown up.

(5) *Night tests.* — Examination of stability at night took place on the night of 7-8 November.

As it was a calm and rainless night, the ships had been stationed at three anchorages of the system some distance apart: the *Armoise* at Port Tudy anchorage, the *Dahlia* near Penfret and the *Basilic* between Ile Verte and the mainland.



TEST OF "BASILIC" STEADINESS ON COURSE

(1st November 1950)

Hyperbolic tracks followed :

10.15 to 11.00 : Red A 03,10.

11.00 to 12.00 : Green C 31,16.

Decca fixes every minute (average speed : 10 knots).

EPREUVE DE TENUE DE ROUTE DU « BASILIC »

(1[er] novembre 1950)

Hyperboles suivies :

10 h. 15 à 11 h. : Rouge A 03,10.

11 h. à midi : Verte C 31,16.

Points Decca toutes les minutes (vitesse moyenne : 10 nœuds).

Observations were taken every minute at the Monitor station and every twenty minutes on board ship, then compared after correction with the hydrographic position, which varied slightly owing to swinging.

Finally:

(1) Observations at the Beg Melen Station, after analysis and reduction, showed a final stability after all corrections had been applied of 2 hundredths on Red and 3 hundredths on Green, elimination being made between 2100 hours and 0600 hours of several drifts of the Green and Red lattices due to faulty supervision.

(2) Observations on the *Dahlia* at Penfret anchorage shoved an average difference, as compared with the hydrographic position corrected for swinging changes of approximately $\mp$ 3 *hundredths on Red* — i. e. $\pm$ 15 metres at this point — and approximately $\pm$ 7 hundredths on Green — i. e. $\pm$ 100 metres. This latter discrepancy, which was almost constant in all measurements, must be attributed to the close proximity of Penfret Island, which acted as a screen in the transmission path of the Green waves.

(3) Observations of the *Basilic,* which was anchored at a point where waves transmitted by the Master station crossed over a considerable portion of land at the edge of the mainland showed similar stability but an average accuracy discrepancy involving a constant systematic error over both lattices of about 10 hundredths, which was an absolutely normal eventuality.

A few jumps of about 23 hundredths occurred on both Red and Green between 0300 and 0600 on November 8, wich must be attributed to an understandable lack of adequate supervision at the slave stations. Otherwise, these night tests, which were carried out under favourable weather conditions, showed a degree of accuracy comparable to that of stability, which was not affected by anomalies of any note. In no case, as could be foreseen at the distance involved, were effects due to night interference detected.

All other things being equal, therefore, the chain may be used just as effectively at night.

(6) *Normal Navigation Trials.* — Movements of a ship between any two points were checked by Decca several times. The purpose of these operations was to see just how far use of Decca could go towards mitigating the unreliability of dead reckoning whatever the course followed. Between Lorient and Belle-Ile, for instance, corrected Decca readings provided a check of position every ten minutes that was better than a land bearing check, at an estimated accuracy of 100 metres Within such limits, therefore, uncertainties due to wind and current under zero visibility conditions may be eliminated, and coverage could certainly be extended beyond 30 miles owing to lower accuracy requirements.

(7) *Range tests.* — An even approximate determination of maximum range of the chain, that is, the distance at which the Decometers cease to be directed with any consistency, did not come within the scope of our trials and would have overtaxed both equipment and personnel. These tests were later to be undertaken, moreover, under the supervision of the Army Air Force, which had set up receivers at St André de l'Eure, or about 400 km. away from the transmitters.

These latter trials are reported to have revealed that the torque observed on the Decometers seemed to reach its limit with the recewers used. The field was reported to be 6 micro-volts/meter and an attempt at audio-reception 15 decibels under that of the English Chain in the Thames. — According to information received from the S.F.R., on the other hand, Decometer reception in Paris itself was satisfactory.

IX. — FUTURE OPERATING CONDITIONS

A normal operational technique such as prevails in Great Britain, Sweden, the Persian Gulf and at the Cape is the only one worthy of consideration. This means that once stability of oscillations has been ensured to within 2 hundredths, adjustment of drift should be secured by direct application of corrections five or six times daily on the part of the phase control operators upon receipt of advice from the monitor station, and not by means of reading corrections on board.

A suitable, that is, an accurate and permanent automatic phase control, provided with a spare, can then be used to reduce other discrepancies. Accuracy of readings at the monitor station and on board ship will be guaranteed to well within the three hundredths obtainable on the Mark IV sets available under the present circumstances, through the use of Survey receivers. Maintenance of the system in proper position then becomes the sole responsability of the monitor station, staffed by an actual officer of the watch. The automatic control would do the rest, and readings would be applied directly by the ships, with no correction other than for a constant error.

Final accuracy to within two or three hundredths, as obtained on the chains mentioned above, would then be possible of attainment.

X. — DESIRABLE EQUIPMENT

Equipment strictly meeting the suggested accuracy requirements should include the following:

(1) *Accurate phase control.* — It can consist of two types:

(*a*) A double phase control consisting of two sets of equipment similar to the one actually available, each including an electronic automatic control and a manual control, both systems working in cascade connection. One is connected to the conversion channel and acts as a *guide,* and the other at the end of the two separate master and slave channels at the discriminator outlet and acts as a *control.*

Accurate regulation of the master channel thus shows up fluctuations that may have escaped from the conversion channel automatic control directly on a Decometer.

(*b*) A single but high-precision phase control operating as a device of the electronic goniometer type and connected to a large dial graduated in hundredths, enabling accurate corrections to be made.

Details concerning the latter may be obtained from the Decca Company. The Persian Gulf Chains operated along these lines, and the final result was a stability of less than two hundredths through the practical elimination of drift of the system.

(2) *Survey receivers.* — The main advantages of the Survey receiver are as follows:

(*a*) As the reference oscillator is not exclusively local but governed by the frequency of the Master station, the various frequency deviations at transmission have no effect on the system and the degree of uncertainty of the reference or zero-setting control of the Decometers is reduced to less than one hundredth.

(*b*) The discriminator is different. An electric balance enables equalization of the voltage supply of the diode detecting valves, and their arrangement as two double diodes (instead of four: V7, V8, and V17, and V18) permits avoidance of thermic inequalities and reliable, linear detection to be acquired.
The DC outlet amplifiers (V10 and V20) have characteristics so selected as to produce appropriate changes of current in the Decometer coils and thus correct the octantal error due to the non-quadratic aspect of diode detection.

(*c*) 110 or 24-volt DC can be supplied to the Survey receivers through a transformer, and power losses thus avoided at the cathodes upon entering the receiver.
A volt meter is moreover attached to the receiver-case, enabling the voltage to be continously checked.

(*d*) Survey receivers are larger and of sturdier construction than ordinary shipborne receivers (which only contain two channels as opposed to three in the former). Owing to this increase in size, the various parts have a better finish and precision of alignment, as well as a dial of greater diameter permitting readings to be taken immediately to within half a hundredth.

X. — CONCLUSION

Lastly, the degree of uncertainty of readings on these Decometers is less than one hundredth of a phase; and if use were made of the two desirable types of equipment described above, a final degree of uncertainty could be attained amounting to two hundredths in 90 % of cases, as compared with the 5 or 6 hundredths observed on the Army Air Force Chain under favourably pre-selected geographical conditions. In other words, the metrical error would have a value varying approximately between 10 and 35 metres, according to the width of the lane.

ANNEXE I

LANE A

Lane A begins in the area surrounding Point M on the parallel Lat. 47°20' and meridian Long. 3°47'. 5 W at the approximate intersection of hyperbolae Red C_1 and Green C_{41}. It includes 7 Red hyperbolae roughly located between B_{23} and C_5.

Swept Lane A follows a broken line M N P Q composed of 3 hyperbolic sections:

From M to N — Red hyperbola C_1
From N to P — Green hyperbola A_{37}
From P to Q — Red hyperbola D_1

Points at which a change of hyperbola is made are marked by means of buoys.

Owing to the nearly rectilinear aspect of the Red hyperbolae in the vicinity of bisector (C_{12}), operational conditions are the most favourable.

— At the level of Point M, width of the area of operation is 5 600 m. At this point, width of the phase lane (phase variation 360°) is about 930 metres.

— On the parallel at Basse Jaune, width of the area is only 2 750 m. and that of the phase lane is reduced to 450 metres.

— On the Pouldu-Lesconil base-line, width of the phase lane is equal to 1/2 the comparison wavelength, or 437 metres.

Note.

If approximate maintenance of a 45-m. degree of accuracy along the swept lane is desired, the following information with reference to the more important Red readings may be noted:

— Near the base-line, readings will have to be taken to within at least one tenth, and corresponding distances on the 1: 25 000 projection will be in the neighborhood of 1.8 mm.

— Near starting point M, readings will have to be taken to within five hundredths of the 1: 25 000 projection, and corresponding distances will likewise be in the neighbourhood of 1.8 mm.

ANNEXE II

PATTERN SPECIFICATIONS

Red Lattice.

Master Station: Old Pouldu Semaphore:

Approximate Position .... { = 47°45'33". 4 N
= 3°31'12" W

Red Slave: Lesconil Semaphore:

Approximate Position .... { = 47°47'39". 9 N
= 3°13'33". 9 W

Distance between stations	53,050 metres.
Adopted propagation speed ..	299,700 km. per second.
Comparison frequency	342.864 kilocycles.
Comparison wavelength	874.107 metres.
Number of Red hyperbolae ..	121

Green Lattice.

Master Station: Old Pouldu Semaphore:
Green Slave: Taillefer Semaphore:

Approximate Position .... { = 47°21'48". 4 N
= 3°09'32". 8 W

Distance between stations ..	51,708 metres.
Comparison frequency	257.148 kilocycles.
Comparison wavelength	1165.477 metres.
Number of Green hyperbolae ..	89

Monitor Station: Beg Melen Semaphore:

Approximate Position .... { = 47°39'10". 6 N
= 3°30'11". 7 W

Distance differences: Red	44,568. 7 metres.
Green	29,438 metres.
Decca co-ordinates of Monitor:	Red A 09.012 Green B 30.742