TRYING OUT THE "LORAN" SYSTEM.

Mission Report concerning the Trials carried out between 5th and 30th April, 1949, on board the "Ailette",

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OBJECT OF THE MISSION.

The Mission was sent out for the purpose of making, on board the "Ailette" while the latter was on duty on the Irish Sea and West Coast of Ireland fishing-grounds, a methodical examination of the possibilities of the Loran navigation and otherwise of verifying the value and accuracy of the Consol system (already examined on the Lugo and Seville Atlantic Stations), in connexion with the use of the Bushmills and Stavanger stations.

Operating Conditions and Equipment used.

At 0700 on 5th April, 1949, left Cherbourg to inspect the banks at the entrance of the Irish Sea, afterwards heading for Cobh. The receiver, installed at Brest by the DCAN of that town was of the *DASa* type manufactured in 1944 by the General Electric Co., model CG-4621 OA, which has the advantage over the *DAS* model that its PRR switch allows the use of a basic pulse recurrence rate 33 1/2 per second—in addition to the low basic pulse recurrence rate (25 per second) ; 8 specific rates following each of the two basic pulse rates. Current was supplied by the normal ship's mains—220/230 volts, 50 to 60 cycles per second.

The overall specification for the receiver-indicator proper and the No. CG 47.335 antenna coil-case met the specification contained in the "Instruction Book for Radio Navigation Equipment Model DAS and Model DAS 2 (Ships 225 A)". However, the complete absence of spare parts and valves might have proved at any moment the cause of an irremediable breakdown of the instrument. Fortunately, by trial and error, it was found that the elementary equipment on board made it possible to operate the instrument satisfactorily and to obtain results consistent with its performance as described in the instructions.

The rigid alignment of the instrument having been attempted several times, the measurement system appearing in perfect condition, it was not until 16th April, when the ship had entered the Irish Sea to North of the 54° N. parallel, that tuning in on stable signals could be undertaken and perfected by means of the following operations:

a) Reparation of soldering of antenna feed cable.

b) Dismounting and examination of the coaxial feed cable connexion.

c) Examination of the antenna terminal cable.

d) Adjustment of antenna impedance to contact 34 corresponding to a relatively short length of antenna—7.50 metres.

e) Adjustment of self-tuners L408, L412, L416 of antenna of frequency-changing-switch and of base oscillator.

One only case of damage, of no very great importance, was noted on 12 April: fusing of general feed unit fuse.

One delicate adjustment should be noted, that of the R114 resistance which controls the operation of the first counter giving the 50 μS markings. A compromise must be arrived at between an accurate adjustment allowing calibration of the markings and the operating of the left-right switch which controls the artificial drift in both directions of the pulses by means of two-way reaction voltages applied to the oscillator through the movement of the above-mentioned first counter.

Graphic possibilities of the zones traversed.

The itinerary provided for by the "Ailette's" instructions included, after leaving Cherbourg, exploration of the fishing banks at the entrance of the English Channel, various

manœuvres in the Irish Sea between the W. coast of Lancashire and the E. coast of Ireland, the vessel having thereafter to round the Irish coast by North and West to return finally to the English Channel banks.

It can be seen from plate No. 1 that the different situations of the receiver barely lent themselves to the use of the ground wave and that observation of the reflected night wave —although rich in results—was affected by unevenness of reception amplitude from the transmitting stations in certain zones lying comparatively near the Master station but at a great distance from the Slave station. Observation of chain 1L6 [*1* indicating the frequency channel of 1950 kilocycles; *L*=Low, the basic pulse recurrence rate (25 per second) and 6 indicating one of the specific recurrence rates of the chain (here 25 6/16)], the Master station of which is at the Faroes (U station) and the Slave station (A station) at the Hebrides, might well have lent itself to almost equivalent reception in spite of the North-South orientation of the UA line. But, as explained in greater detail further on, conditions for making use of graphs in the greater part of the East zone frequented by the "Ailette" had to be considered prohibitive on account of its close proximity to the exterior base line. This is in an area where the hyperbolae are so widely spaced on the special charts that, on the one hand they are no longer drawn while, on the other hand, linear interpolation is inaccurate and therefore not advised.

Observation of chain 1L5 [*1* corresponding to the 1950 kilocycles frequency channel; *L*=Low—indicating a low basic pulse recurrence rate (25 per second); and 5 indicating the specific recurrence rate of 25 5/16] the Master station of which is at the Faroes (U station) and the Slave station (K) at Iceland, was rendered very irregular by the difference of distance from the receiver to each of the two stations in the case of certain areas traversed by the "Ailette" where very often, in the daytime, the ground wave coming from the Faroes was alone received.

However, while the vessel was cruising along the West coast of Ireland, a certain number of observations were in accordance with the approximation provided for in spite of the proximity of the base line.

Theoretical Accuracy.

The geometrical study of precision areas arising from the position of the receiver in relation to the base line, leads to the following approximate formula; in this formula, the mean linear difference to be expected between the point observed and the true point is given for 50% of the observations.

$$y = 0.162 \text{ W. } x \text{ in miles}$$

x being the mean functional error measuring the uncertainty in microseconds and resulting from three causes:

a) faulty superposition of pips ;

b) errors in synchronism of transmitting stations ;

c) accidental differences during transmission ;

due to inaccurate sky wave correction or to different velocities. It is admitted that—aside

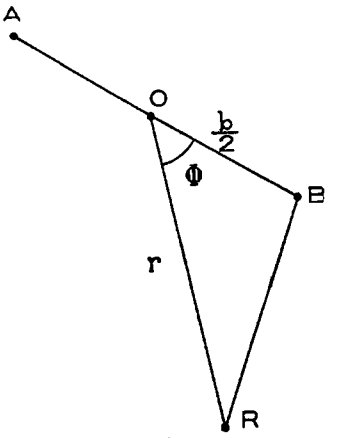

FIG. 1

from any inexperience of the operator—this error is at a minimum of 1 microsecond for clear and steady ground waves and that it can waver between 2 and 6 microseconds for reflected night waves.

W being the geometrical factor the value of which is:

$$W = \frac{r}{b} \cdot \frac{1}{\sin \theta}$$

where b is the length of the base line:

460 miles for UK of 1L5
210 miles for UA of 1L6

r the distance from the vessel to centre O of the base line and θ the angle of the vector radius RO with the base line AB. The zones thus defined by the factor are limited by circumferences passing through A and B (fig. 1).

Let :

1.—Be considered as geometrically usable only zones where, for the direct ground wave, the factor 0.162 W is inferior to 2 Miles for 1 microsecond of probable error ;

2.—Night waves be excluded from the usable zone :

a) The area inside the curves drawn at 250 miles from each station ;

b) The area adjacent to the exterior base line delimited by position lines :

$$\theta = \text{arc sin } \frac{b}{100} \text{ (b in miles)}$$

drawn from centre O (fig. 2).

The angle θ limit is thus 30° where b = 200 (which is the case in the 1L6 chain); 15° where b = 450 (which is the case in the 1L5 chain). Because of the tracks followed by the vessel, observations were frequently made outside of these conditions, particularly as regards the 1L6 chain. In this case the angle θ was never appreciably greater than 13°.

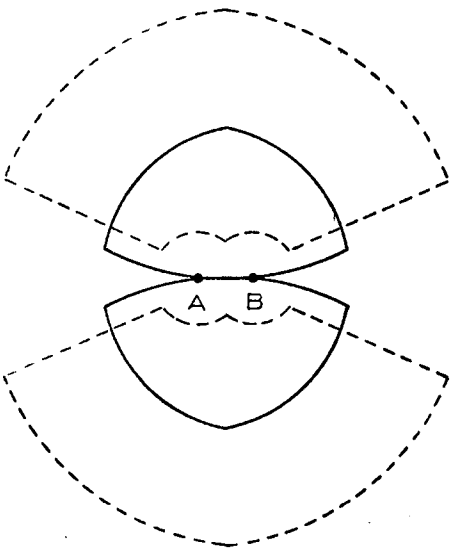

FIG. 2

Probable functional error.

With regard to direct waves, once allowance has been made for irregularities of transmission synchronisation, the most probable measurement error, with signals properly superimposed, should hardly exceed 1 microsecond.

For indirect night waves the most probable measurement error, account having been taken of the uncertainty of the mean sky wave correction given by the tables and of random errors arising from time-differences in the ship's run, is on an average, 2 microseconds at more than 300 miles from a station. Below 300 miles it may reach 5 to 6 microseconds. It may therefore be said that:


Groenland
Islande
Féroës
Shetlands
Hébrides
Iles Britanniques
Londres
EUROPE
IL 6
IL 5
Couverture Loran utilisable aux abords de l'Europe
Portée approximative de l'onde directe sur mer = 800 milles - Traits pleins
— " — de l'onde réfléchie sur mer = 1300 milles - Traits tirets.

Planche n° 1

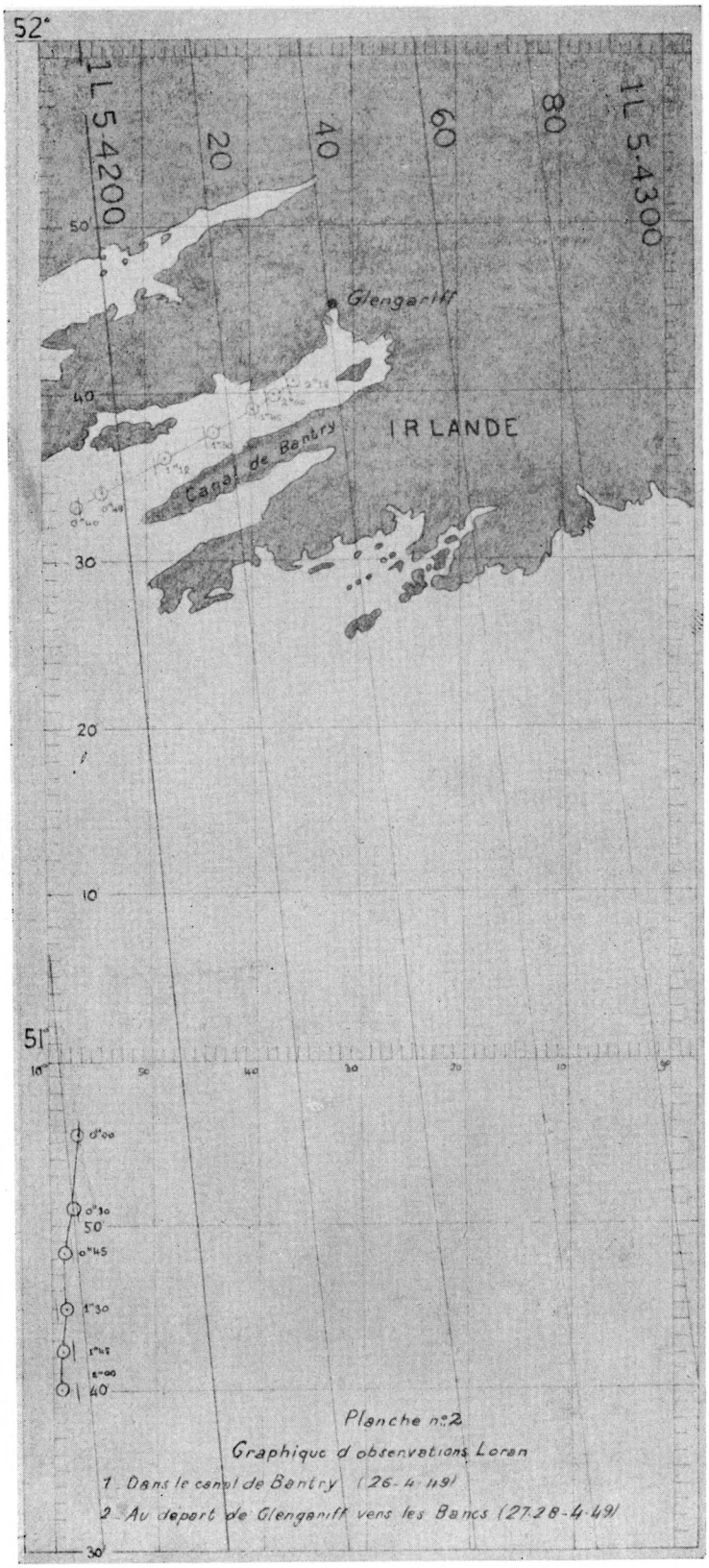

Planche n°2

Graphique d'observations Loran

1. Dans le canal de Bantry (26-4-49)

2. Au départ de Glengariff vers les Bancs (27-28-4-49)

$y_1 = 0.162$. W x 1 for the direct waves 1L5 and 6
$y_2 = 0.162$. W x 2 for night waves 1L5
$y_3 = 0.162$. W x 5 for night waves 1L6
(Hebrides at less than 300 miles).

It having been found impossible to assure a strict continuity of observations because of navigation at the limit of the areas of effective range, operational characteristics have been grouped into four average observation zones: 1, 2, 3 and 4.

— Zone 1 being approximately centred on the point: $\varphi = 49°10'$ N. $G = 6°30'$ W. at the English Channel entrance and referring exclusively to the night wave.

— Zone 2: South of the Isle of Man centred on the point: $\varphi = 54°00'$ N. $G = 5°20'$ W. on the limit of ground wave 1L5 and in night wave 1L5.

— Zone 3 covering the N.W. coast of Ireland around the point: $\varphi = 55°00'$ N. $G = 8°40'$ W. in the ground wave 1L5 and at the limit of ground wave 1L6.

— Zone 4 from the S.W. extremity of Ireland by $\varphi = 52°00'$ N. $G = 10°30'$ W. at the limit of 1L5 (day) and 1L5 and 1L6 (night).

In the following tabulation the numerical values of the preceding precision elements are given for each central point, if care be taken to interpolate generously in intermediate navigation.

Chain 1L5 — UK = b = 460 miles

Zones	θ	r (Miles)	Probable Error per μS or 1.162 W	Theorical probable error in miles	
				day: 1 μ S	night: 2 μ S
1	58°	910	0.37	0.37	0.74
2	47°	650	0.31	0.31	0.62
3	57°	520	0.21	0.21	0.42
4	64°	700	0.27	0.27	0.54

Chain 1L6 — UA = 6 = 210 miles

Zones	θ	r (Miles)	Probable Error in microseconds	Theorical probable error in miles	
				day: 1 μS	night: ε μ S
1	1° to 2°	630	13 to 25	unusable	unusable
2	13°	360	1.3	unusable	6 with ε = 5 μ S
3	13°	290	1	uncertainty limit 1 mile	6 with ε = 6 μ S
4	13°	480	1.8	unusable	9 with ε = 5 μ S

These tables being established on purely theoretical considerations, attempts were even made during the various observations at measurements outside usable areas. The only limitation was reception intensity ; and land intervening between the transmitters and the receiver, especially when the land is adjacent to one or other of the stations, considerably modifies the range of the system by direct day wave. The range is easily reduced to 300 miles when travel overland is greater than 20 miles. The effect is much less for night waves and broadcasting is not affected by any land which does not lie within 20 or 30 miles of the transmitter.

It is moreover evident from Table (1) that :

1) It was impossible to make use of graphs on chain 1L6 for direct wave in the three areas 1, 2 and 4 and possible at the limit between 3 and 4.

2) It was possible up to the limit between 3 and 4 on 1L5.

3) The night wave was usable in the 4 areas for 1L5 and at the limit for 1L6 in one single zone with very pronounced graphical uncertainties.

Results obtained.

Observation and use of two simultaneous chains were impossible except under very restricted theoretical conditions on ground wave, on 24th and 25th April, with close one-mile approximations on the West coast of Ireland around the approximate positions $\varphi_1 = 54°45'$ N. and $G_1 = 9°00'$W. and $\varphi_2 = 53°30'$ N. and $G_2 = 10°30'$W.

It was found possible to make day observations on 1L5 chain under favourable conditions (0.7 mile average accuracy) South of zone 3, on 24th April by $\varphi_3 = 55°10'$ N. and $G_3 = 8°25'$ W.

During most of the other days, because of the comparative nearness of the Faroes Master station U common to the two chains, the pulse of this chain 1L5 station was received with sufficient strength by day on direct wave, but the pulse of Iceland station K of the same chain was undistinguishable.

The two pulses of chain 1L6, coming from the Faroes (U) and the Hebrides (A) were received by ground wave in the daytime; but remained useless partly on account of their weakness but chiefly because of the geometrical unsuitability of the zone.

In almost all the positions of the vessel, the indirect waves of the two chains were received by night with variable strength and steadiness, except at anchorages on the English coast, in the roadsteads and in the Channel inshore. In this case E_1 waves, which were almost invariably followed by an important train of E_2 and F waves, had to be aligned.

INFLUENCE OF VARIOUS OBSERVATION ELEMENTS.

Elements intervening either in the possibility of alignment of the pulses or in the utilization of the measurements obtained are the following:

a) *Distance from the transmitter and Time of day:*

The direct or ground waves were sufficiently perceptible and serviceable to within 500 miles from the transmitters, between zones 3 and 4 on the W. coast of Ireland, with no intervening land. They were almost always useless by night because of their weakness.

On an average, this direct wave appeared in the morning towards 0830 (sunrise about 0620) and about the same time the night waves became weaker; it increased in power up till 1000 to disappear, on an average, about 1900 (sunset towards 2100).

It was only towards 2200 that the night wave became sufficiently powerful and steady, and the secondary trains E_1, E_2, F_1, F_2 continued to increase in power up till 0200. Generally, therefore, there was a period of from two to three hours between 0500 and 0800 and between 1900 and 2200 during which no observation was satisfactory.

b) *Geographical position, atmospheric conditions and interference:*

In the zone of comparatively high latitude frequented by the "Ailette", the atmospheric parasites, outside twilight periods, remained limited to an acceptable degree. During western gales encountered on the West coast of Ireland, the receiver showed remarkable strength ; only violent rain squalls causing momentary confusion to the scope.

On the other hand, radiotelephonic transmission on 137 to 152 metre wave length proved an almost insuperable obstacle in aligning the pulses, the filtre meant for this purpose not being adapted to protect the 146 metre wave length of the LORAN transmissions.

On the Channel and Irish Sea fishing banks, the encounter of groups of trawlers conversing continually on frequencies absolutely interrupted all Loran observation, the time base of the screen being literally "see-sawed" by the transmissions. Conversely, it should be emphasized that, contrary to some affirmations, radiotelephony appears in no way to be disturbed by Loran waves.

c) *Ground effect:*

The range of Loran direct waves appears to be greatly influenced by passage over intervening land. In the Irish Sea only night reception was possible because waves coming from Iceland and the Faroes had to cross more or less extensive strips of land. As soon as the ship had cleared the narrower waters and reached the open sea North of Ireland, power of reception very appreciably increased.

d) *Directional influence of reception antenna:*

The antenna being comparatively short and almost rigidly vertical, no directional effect was noted. When the ship is rolling, even extensively, reception remains steady in spite of frequently violent shocks.

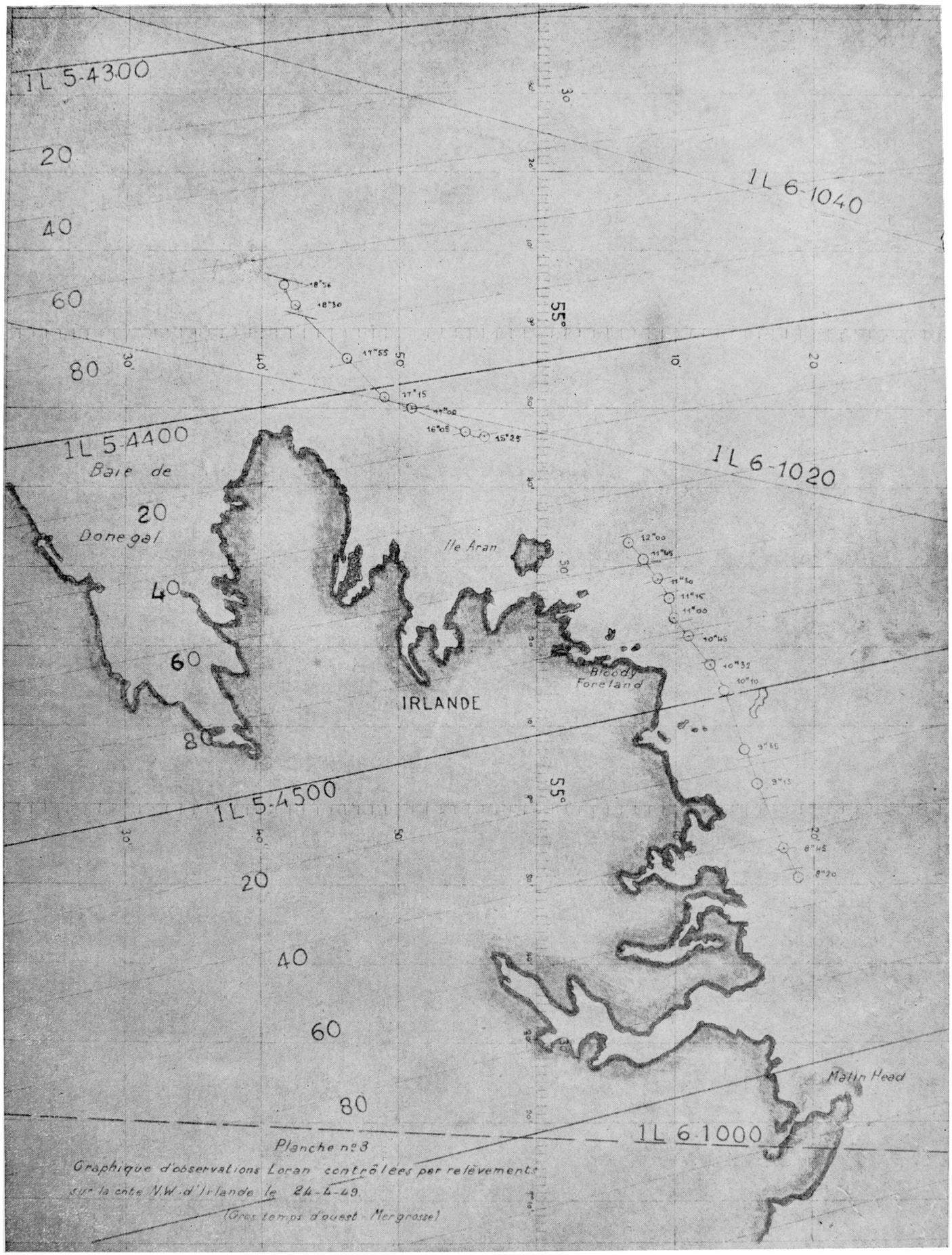

Planche n°3

Graphique d'observations Loran contrôlées par relèvements sur la cote N.W. d'Irlande le 24-4-49.

(Gros temps d'ouest - Mergrosse)

e) *Separation of direct waves and night waves:*

The time of day and the distance to the stations are elements generally sufficient to identify pulses of the same nature. The appearance of signals is not a sufficient guide, for the ground waves proved, at the distance limits used, almost as sensitive to "splitting" (1) as the night waves.

Only the periods of co-existence of the two waves morning and evening can give rise to confusion, but the weakness of the signals during those periods is in itself a sufficient obstacle to any satisfactory measurement.

The rule is:

1) To make *continuous* observations which avoid confusion and show up on the reckoning the great differences which result from these identification errors.

2) To abstain from all measurement during the periods of jamming, fading and splitting; the last-mentioned occurs on the night waves at fairly regular intervals and averages 1 minute.

3) Never to omit aligning the pips farthest to the left, obtained with the maximum gain.

Handling the receiver.

A good method is, having adjusted the amplitude balance which puts the pips in equilibrium with the average gain, to keep the screen at the "Sweep Speed No. 2" scale between each reading, the pips being kept in alignment by very delicate manipulation of the Left-Right switch. Alignment is then lost more or less slowly as the vessel moves.

Accurate matching on the magnified sweeps is obtained by using both hands, one acting on the Fine Delay Control, the other on either the Amplitude Balance, the Gain, or the Left-Right switch. The dexterity necessary for this manipulation is acquired in a comparatively short time.

At anchorage, at a fixed point, or within open sea range from the transmitting stations, accuracy of matching can be methodically checked by leaving the pips superimposed on the Sweep having the greatest degree of magnification, i.e. Sweep Speed No. 5. In any case, for satisfactory results, equivalent pip-markings of maximum size must be matched.

Special observations.

An extract from the whole group of over 130 acceptable observations, made during the cruise, is given in Annex I(2). In these tables a few performances particularly characteristic of the system in areas within range have been selected:

1) Continuous checking of the vessel's track, during the day-time, using land fixes, on the N.W. coast of Ireland on 24th April, 1949, by means of ground waves (Plate 2), showing a mean accuracy of seven-tenths of a mile on chain 1L5 and an accuracy of 1 to 2 miles on 1L6, in the zone between 3 and 4.

2) In the Bantry channel, a succession of Loran position lines observed by night on the sky wave of chain 1L5, the accuracy of which was never less than 1 mile in spite of the waves having to cross the narrow strip of land which forms the Kenmare peninsula.

On leaving Glengariff on 27th April, 1949, heading 185°, a check on the reckoning showed an average difference of less than a mile from the reckoning on the night wave by 1L5 position lines (Plate 3).

3) On 29th April, 1949, as the ship was heading towards the English Channel after having cruised in many directions seeking for groups of trawlers, an error of 12' westwards appeared on the reckoning. This error was revealed exclusively by a series of longitudinal Loran position lines observed on the 1L5 night wave between 0030 and 0145 hours.

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(1) "Splitting":  breaking into two or more humps.

(2) Not reproduced here.

BRIEF EXTRACT FROM ANNEX I

Loran observations carried out on board the " Ailette " from 17th to 30th April 1949

POSITION ERRORS NOTED

From Dublin to Fleetwood and Belfast

Out of 9 *observations :*

No error			Once.
Error of	1	mile	3 times.
—	1,5	miles	3 times.
—	2	miles	Once.

From Belfast to Glengariff

Out of 31 *observations :*

No error			5 times.
Error of	0.3	mile	Once.
—	0.5	mile	4 times.
—	0.7	mile	Once.
—	1	mile	10 times.
—	1.5	miles	Once.
—	2	miles	Once.
—	2.5	miles	Twice.
—	3	miles	Twice.
—	7	miles	Once.

From Glengariff to Cherbourg by Channel banks

Out of 10 *observations :*

No error			Once.
Error of	1	mile	Once.
—	2	miles	Once.
—	2,5	miles	Once.
—	3	miles	Once.
—	4	miles	Once.
—	10	miles	Once.
—	12	miles	Once.
—	13	miles	Once.

From Channel banks to Cherbourg

Out of 5 *observations :*

Error of	0.5	mile	Once.
—	1	mile	Twice.
—	1.5	miles	Once.
—	2	miles	Once.

CONCLUSION

To sum up, the Loran position lines observed (which were limited owing to the absence of two chains that could be used simultaneously) proved a reliable, easy and accurate navigation aid, within the limits of coverage, in areas where nothing but the open sea intervened between the ship and the stations and whenever observations were made by day wave from 3 hours after sunrise till 2 hours before sunset and by night wave from 1 hour after sunset till 1 hour before sunrise. During these favourable periods the accuracy in plotting the position lines is within 1 mile and reaches half-a-mile for a practised observer. The duration of observation of the reading and concluding from it is not more than two or three minutes. Outside of those periods, or when land intervenes near the transmitter or the receiver, particularly in open roadsteads, the observations are more irregular and results can only be used with caution. It was not possible to verify the accuracy of the fix depending on the intersection angle of the hyperbolae because of the inapplicability of chain 1L6. The 1L6b chain would have given very good results but has been out of operation since 1946.

The solidity and simplicity of operation of Loran (which well deserves its name of "long range navigation") justifies the confidence that has been placed in it by several thousands of American vessels and aircraft.