MEMORANDUM ON ESTABLISHMENT OF COASTAL CHAIN OF GEODETIC SIGNALS BY TRAVERSE

by *Ingénieur Hydrographe en Chef* ANDRÉ BRUNEL

PURPOSE OF MEMORANDUM

The purpose of the method described in this memorandum is to obtain, by traverse from a known geographic position, the positions of signals set up on a fairly even coastline, whenever access to the interior in order to establish a network of geodetic triangles is either impossible or extremely difficult. Such cases occur in certain colonial possessions, as in the Cameroons, where the country apart from the coast has hardly been explored and for which no triangulation exists, since it would involve much time and expense.

The operational method recommended herein applies to the practice followed in making so-called running surveys, but it may be well at this point to stress that running should not be considered as synonymous with careless. Speed must not preclude care. It will in fact be seen that a meticulous, methodical approach enables the obtaining of results which, while they may not be strictly accurate, are at least adequate for setting up a coherent set of signals that may be relied on for operations at sea.

PRINCIPLE OF METHOD

Signals of the « Pyramid » type are built approximately every 10 kilometres at A_1, A_2... A_n, beneath which *centred* theodolite stations may be set up.

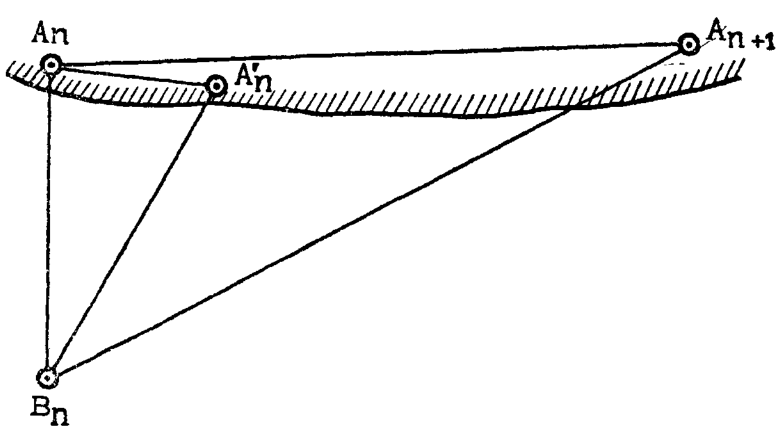
The location of each pyramid should be so selected that the one preceding and following may be seen from it.

The method consists in determining for each section such as A_nA_{n+1}:

— the astronomical azimuth of A_nA_{n+1} ;

— the distance from A_n to A_{n+1}.

No special remarks need be made as to measuring the azimuth, which should be done according to ordinary methods.



(FIGURE 1)

In order that distance A_nA_{n+1} may be obtained, the ship is anchored at B_n in such a way that $A_n B_n$ is approximately perpendicular to the coast.

Base $A_nA'_n$ is then measured out parallel to the shore, and extended by using the ship as a signal.

Stations for this purpose are set up simultaneously at $A_nA'_n$ and A_{n+1} and a bearing on the ship's mast is taken from each at the same instant. A sight is then taken from A_n on A'_n and A'_{n+1}; from A'_n on A_n; and from A_{n+1} on A_n.

— In triangle $A_nA'_nB_n$, angles at A_n and A'_n have been measured, as well as side $A_nA'_n$: A_nB_n may therefore be computed.

— In triangle $A_nA_{n+1}B_n$, A_nB_n has already been computed, and angles A_n and A_{n+1} are measured. A_nA_{n+1} may therefore be computed.

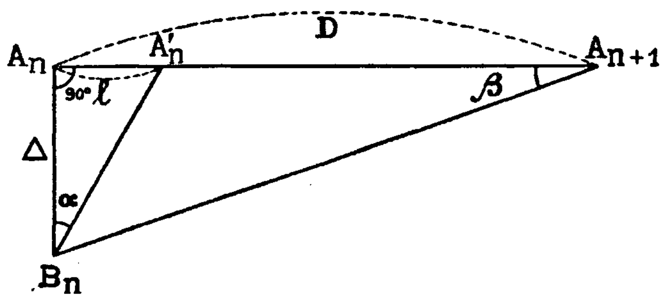
Knowledge of the azimuth and length of each section makes it easy, from an initial signal of known position, to obtain the position of one after the other by traverse.

It may be pointed out that accumulation of errors is reduced to a minimum owing to the fact that each section, such as A_nA_{n+1}, is dealt with separately, an azimuth and base measurement being obtained for each.

DEGREE OF ACCURACY THAT MAY BE EXPECTED FROM MEASUREMENTS. DISTANCE AT WHICH SHIP SHOULD BE ANCHORED

We assume that the base may be measured with a degree of accuracy of 1/5,000, or to within 0.10 m. for a base of 500 m., and that the maximum error in angle measurement of the triangles is 3".

Let us assume the existence of theoretical conditions such as those in Figure 2:



(FIGURE 2)

With $A_nA'_nA_{n+1}$ along the same line, let us put:

$A_nA_{n+1} = D = 10{,}000$ metres.

$A_nB_n = \Delta$; $A_nA'_n = l = 500$ metres.

We have:

$$D = l \cot \alpha \cot \beta ;$$

if $/dD/$ is the maximum error that can possibly occur along D, we have:

$$/dD/ < \frac{/dl/}{l} + \frac{2\,(1 + \tan^2 \alpha)}{\tan \alpha} /d\alpha/ + \frac{(1 + \tan^2 \beta)}{\tan \beta} /d\beta/.$$

The error with respect to α should be counted as double, since this angle has been derived from two angular measurements: that of angle A_n and of angle A'_n.

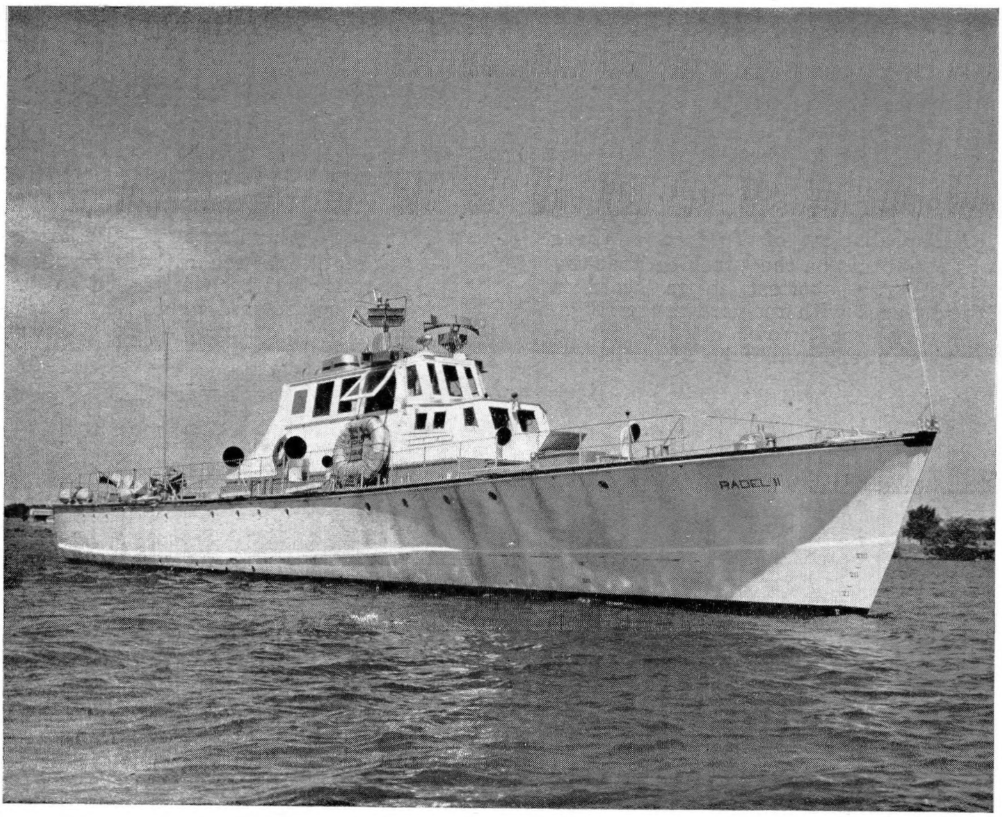


Fig. 1. New Experimental Vessel « Radel II ».

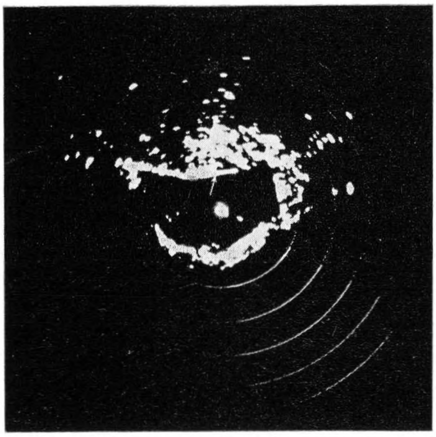


Fig. (2) Type-268 Radar Display. — Radar display of Toronto Harbour as it appears on the 5-inch cathode-ray tube. The shortest range scale is being used with 100-yard range rings. Pier 10 (see arrow) at the foot of Yonge Street cannot be identifield.

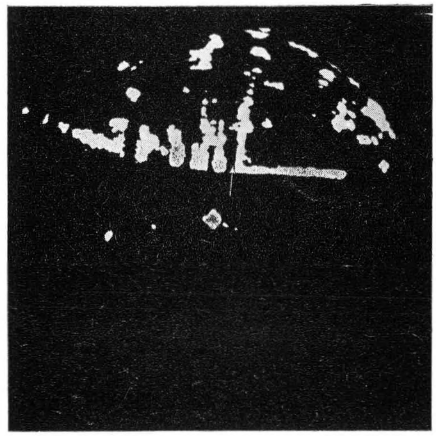


Fig. (4) Experimental Navigational and Docking Radar Display. — Radar display of the 10-inch cathode-ray tube. The range has been expended so that only one 1000-yard range ring is visible. Pier 10 can now be cleary seen.

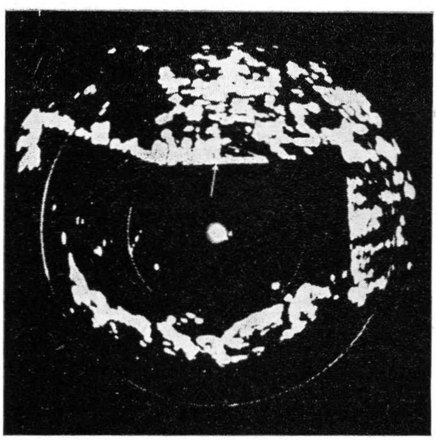


Fig. (3) MMR-B Radar Display. — Radar display of Toronto Harbour as it appears on the 7-inch cathode-ray tube. The shortest range setting 2200 yards) is being used with 1000-yard range rings. Note that Pier 10 can just be identifield.

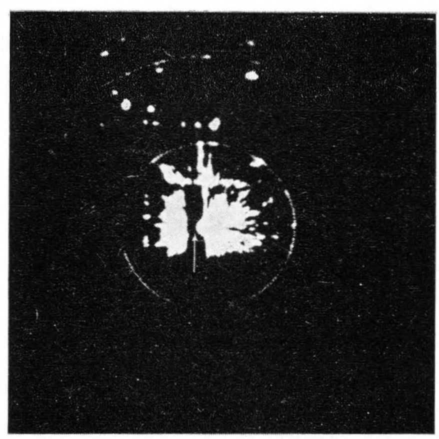
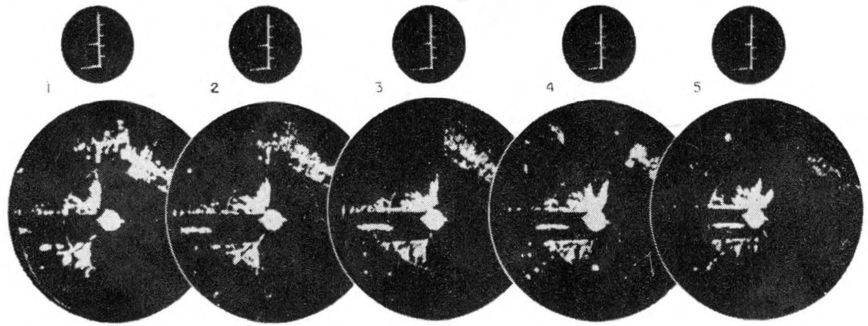


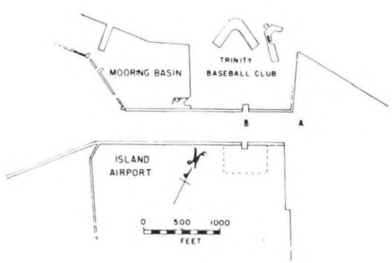
Fig. (5) Experimental Navigational and Docking Radar Display. — Radar display of Pier 10 at the foot of Yonge Street, Toronto Harbour. The M.V. « Radel II » is docked on the east side of the basin which is 200 feet wide and about 700 feet long. 200-yard range rings are used.

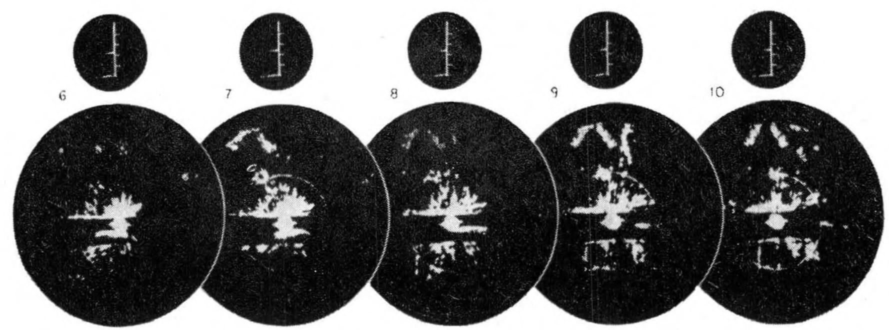
Fig. (6)



NOTE --- The large circles present a photographic sequence of the 10-inch display of the new Experimental Navigational and Docking Radar on board the M.V. "Radel II" proceeding from Position "A" to Position "B" (see sketch). The extremely short minimum range of this radar permits echoes from the bow and stern of the 110-foot vessel to appear. These may be seen extending beyond the echo at the centers of the circles, indicating the heading of the vessel as it manoeuvres to pass the freighter.

The photographic sequence of the electronic depth display, operated from an echo sounder on the "Radel II", appears in the small circles. The depth scale covers 50 feet, with calibration marks at 10-foot intervals. A depth varying between 21 and 24 feet is indicated.





PHOTOGRAPHIC SEQUENCE OF SHORT-RANGE DISPLAY OF EXPERIMENTAL NAVIGATIONAL AND DOCKING RADAR
SHOWING THE M.V. "RADEL II" PASSING A LARGE LAKE FREIGHTER
IN WEST ENTRANCE OF TORONTO HARBOUR

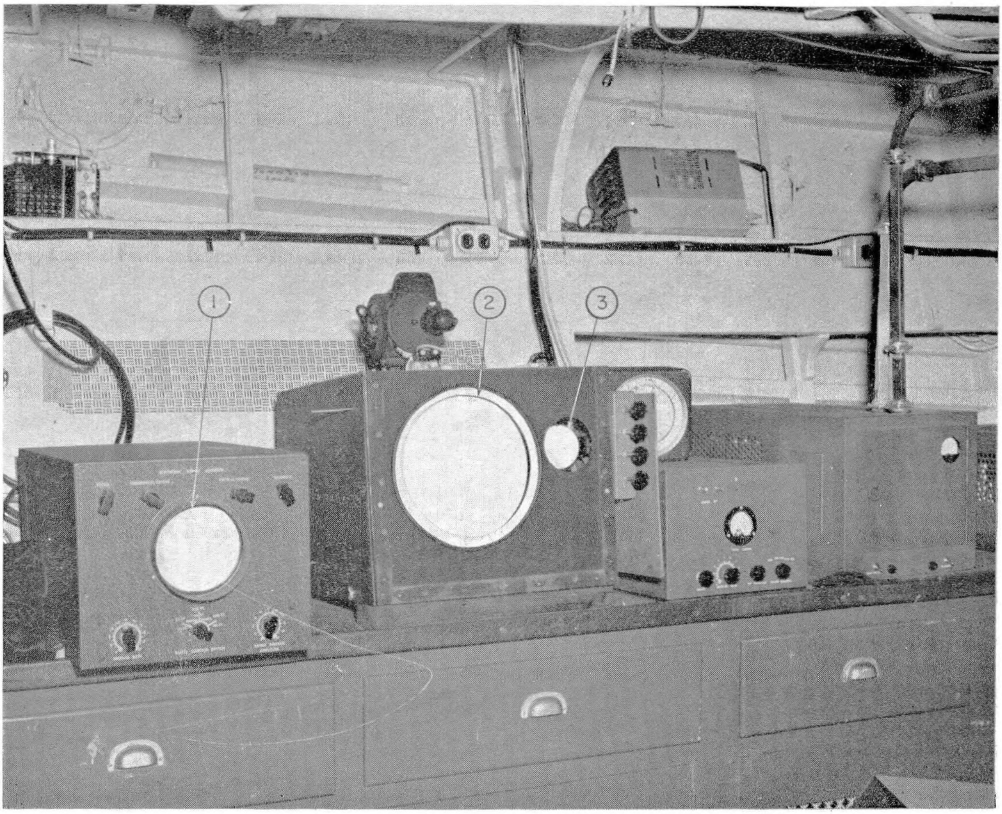


Fig. 7. Experimental Navigational and Docking Radar.
(1) Master Depth Viewing Display; (2) Experimental Navigational and Docking Radar Display; (3) Photographic Depth Display.

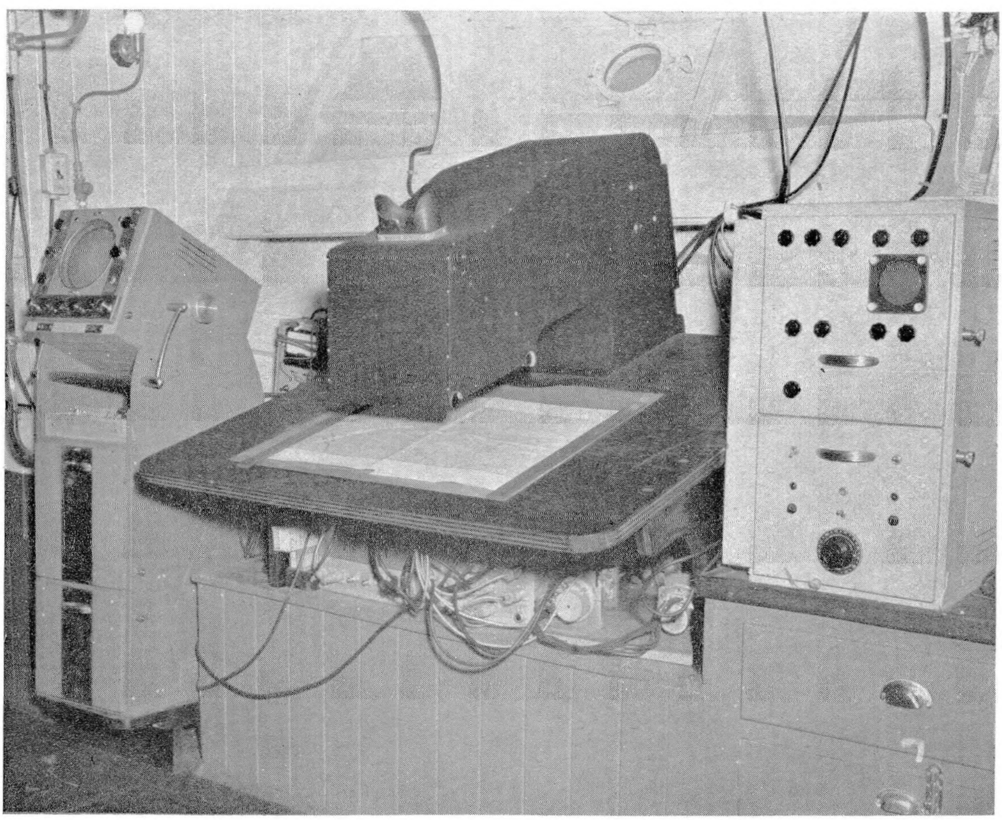
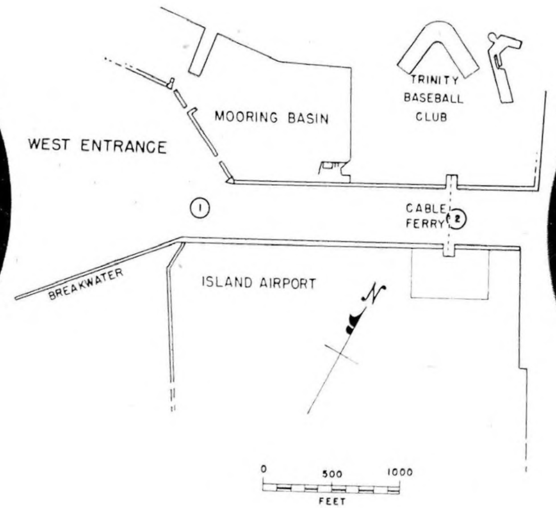


Fig. 8. Radar and Chart Matching Unit.

Fig. (9)

Vessel Just Outside West Entrance



Positions of vessel shown at (1) & (2)

West Entrance of Toronto Harbour

Vessel Near Cable Ferry

PPI Displays with Short-Range Sweep
(Receiver Gain Reduced to Improve
Definition of Nearby Objects)

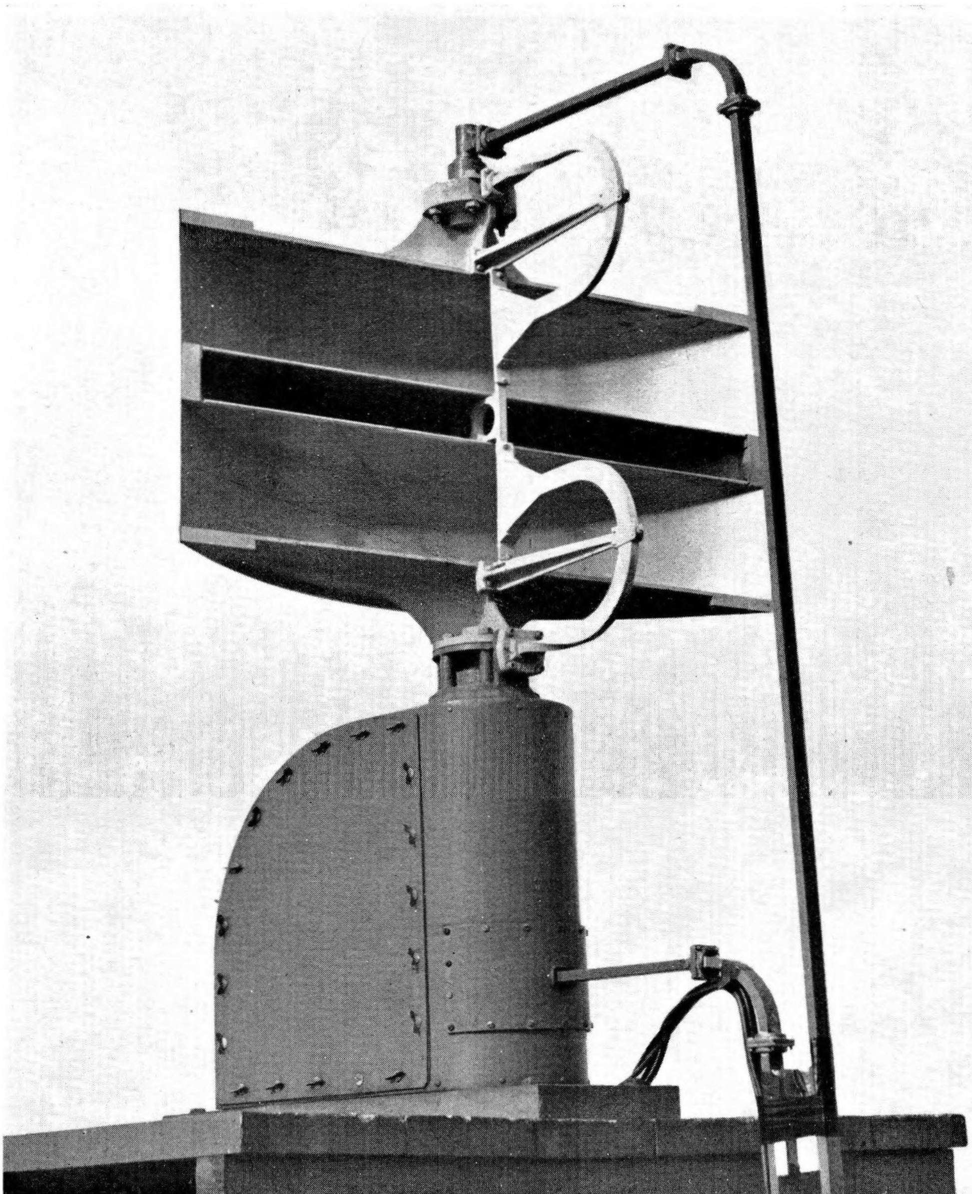


Fig. 10. Experimental Dual Antenna for Navigational and Docking Radar. — This type of antenna physically separates the transmitting and receiving sections of the radar, producing a smaller central dot, as required for extremely good minimum range performance.

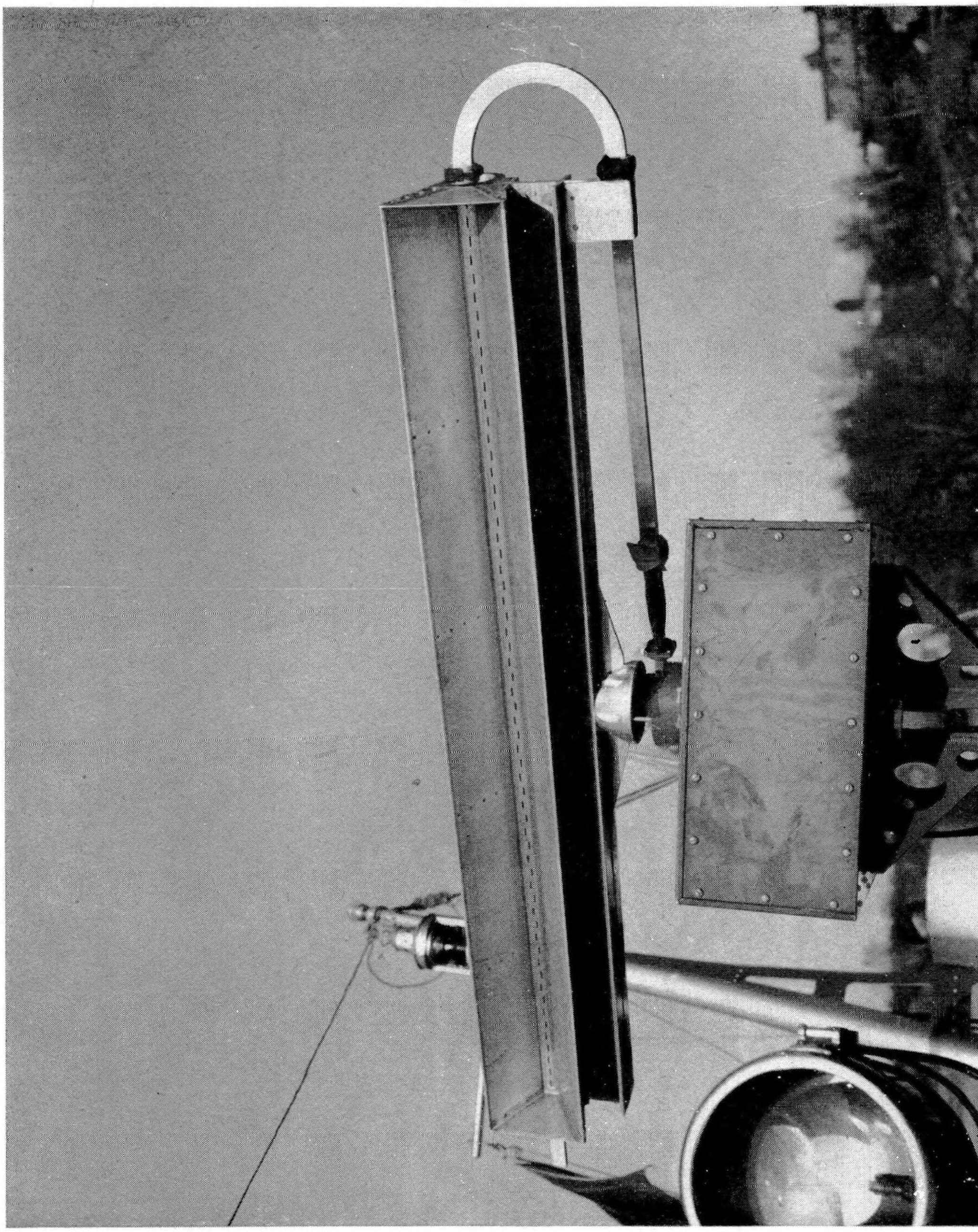


Fig. 11. Experimental Slotted Wave Guide Antenna for Operational Trials of Various Marine Radars. — The performance of this type of antenna is singularly free from false echoes at wide angles, and in addition, it is so constructed that wind resistance is small compared with that of other types of antenna of the same radiating area.

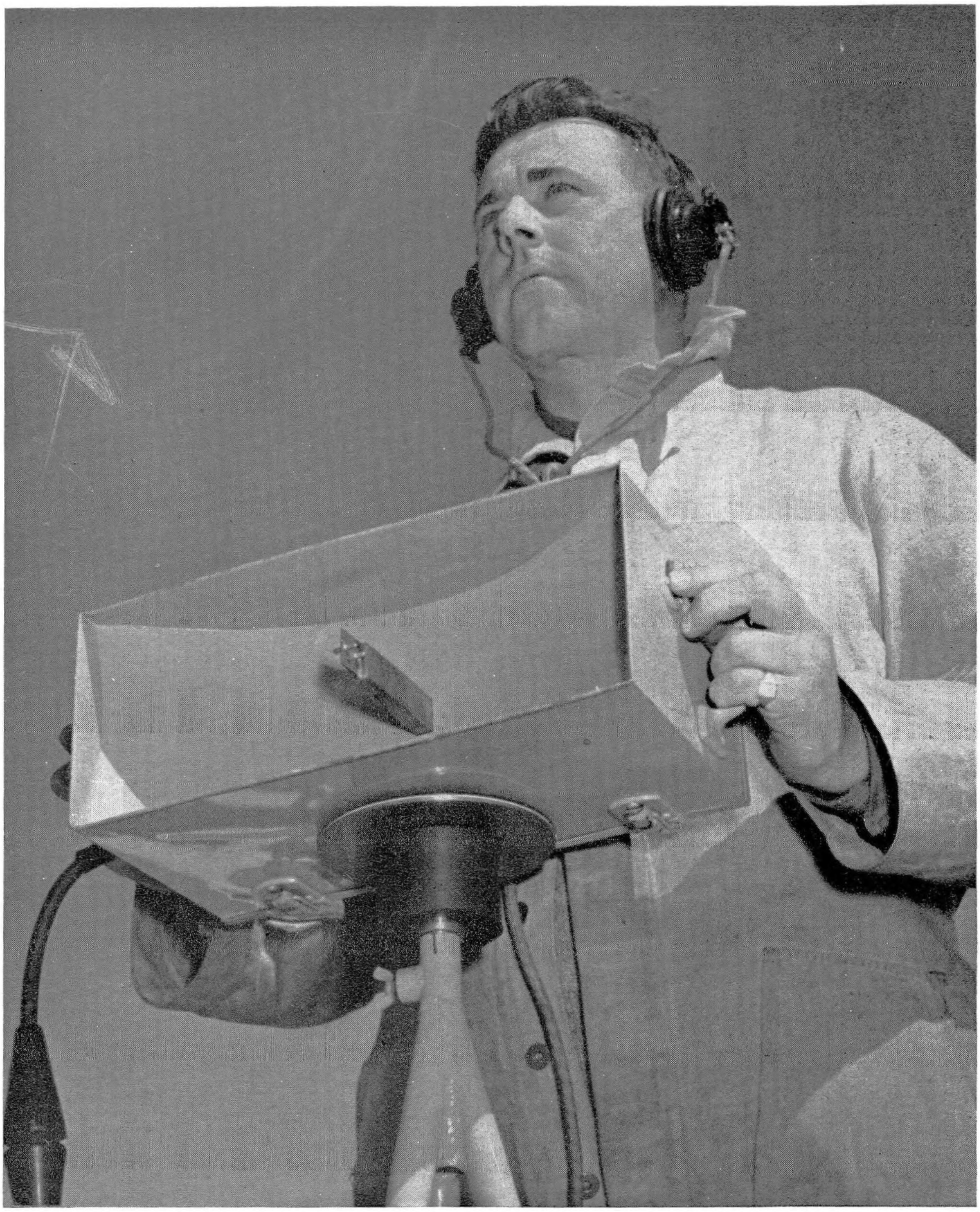


Fig. 12. Microwave Direction Finder.

With the numerical values assumed above and evaluating Δ in kilometres, we get:

$$dD = 2^m + 0.14 \left(4.1 \ \Delta + \frac{11}{\Delta}\right)$$

It may therefore be seen that the error is quite large if the ship is anchored very close to or very far from shore. The error is minimum if:

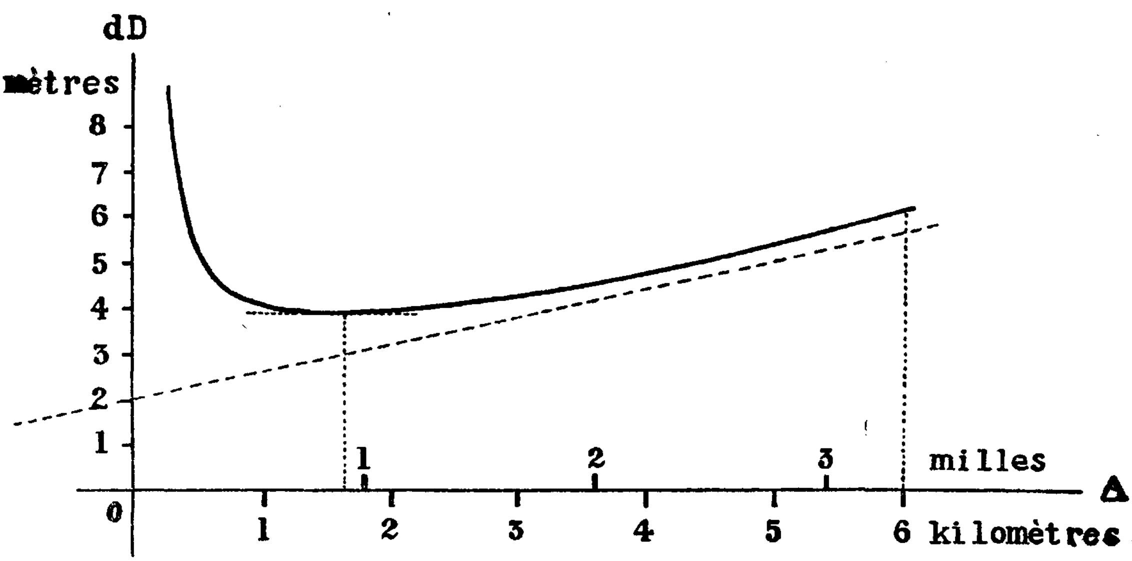
$$4.1 \ \Delta = \frac{11}{\Delta}$$

i.e., if: $\Delta = \sqrt{\frac{11}{4.1}} = 1.6$ km. $\#$ 1 mile.

The value of this minimum is:

$dD = 3.9$ m.

The following graph gives dD for values of Δ from 0 to 6 kilometres.



(FIGURE 3)

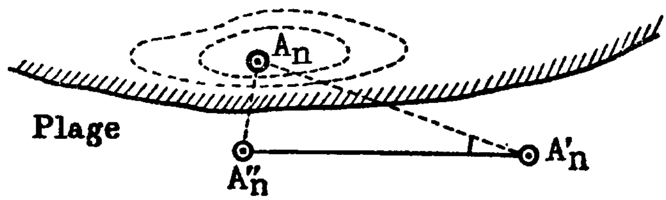
It may be seen that by anchoring the ship one mile from shore dD is at a minimum and on the order of 4 m.; for $\Delta = 3$ miles, dD is on the order of 5 m.

It will not always be possible to make use of the best theoretical conditions, if the ship's draught is large. In any case, the ship should choose its anchorage by taking a compass bearing of signal A_n and by measuring the distance by range-finder.

MEASURING OF BASE

This may be accomplished through the use of standard base-measuring equipment but quicker results will probably be obtained by working with a DANGER instrument, of which two models are available: one equipped with invar tape, supplying 1/20,000 accuracy, and the other with steel tape, with 1/10,000 accuracy. With either it should be easy to obtain an accuracy of 1/5,000. Forward and return sets of measurements should of course be taken, and use made of the average length.

As signals A_n and A_{n+1} are almost invariably set up on heights ashore above high water-mark, direct measurement of the base from A_n will probably be difficult in the majority of cases, since the terrain in the vicinity of the signal will generally not be horizontal. Under these circumstances, it will be necessary to



(FIGURE 4)

proceed as follows: A'_n should be chosen *on the beach* at about 500 metres from A_n, the distance being evaluated by sighting the stadia rod with the theodolite set up at A_n. A strong metal stake should be driven into the ground at point A'_n as far down as it will go. The base should then be measured with the DANGER instrument along a contour line. A metal stake should be driven at A''_n and checked for verticality by plumb-line.

This stake should be sighted from A_n and A'_n, where the theodolites have been set up. It should be a simple matter in triangle $A_n A'_n A''_n$ to proceed from the measured base $A'_n A''_n$ to side $A_n A'_n$, since the angles at A_n and A'_n have already been measured.

MEASUREMENT OF $A_n A'_n A_{n+1}$ ANGLES

In order that 3" accuracy may be obtained, Wild T_2 or T_3 theodolites should be used. Stations should be carefully centred. The vertical axis of the theodolite at A'_n should be sighted from A_n.

Sights taken on the mast of the ship from the stations should be simultaneous. They should occur at the precise instant a flag previously hoisted to the masthead is brought down. Eight simultaneous sights should be taken at hours H, H + 15 m, H + 30 m, etc...; land sights should be taken in the interval. Measurements should be made alternately with the glass at the left and right, with 0°, 90°, 135°, 45°, etc..., taken as origins.

ACCURACY OBTAINABLE BY THIS METHOD

Since the swinging of the ship prevents the mast from remaining stationary, each measurement will of course have to be dealt with separately and the average of the 8 computed values for D used.

Let us assume that Δ is between 1,000 and 5,000 metres; l = 500 m., dl = 0.10 m.; and angle accuracy on the order of 3". Since the error in azimuth, which may attain 10", only supplies an error of 0.5 metres on the signal at 10,000 m., the total error as to the relative position of A_{n+1} with regard to A_n will therefore be on the order of 5 m.

Along a coast 200 kilometres long, which is the length of coast in the Cameroons, the network would involve the establishment of 20 sections similar to $A_n A_{n+1}$. The relative error of one extremity of the net with reference to the other, under the operational conditions described above, would be less than 20 x 5 = 100 metres, and the mean square error would be:

$$5 \sqrt{20} < 25 \text{ metres.}$$

Careful determination of the geographical positions of the end stations by prismatic astrolabe and their adjustment will enable a sufficiently accurate coastal scheme for hydrographic surveying purposes to be acquired, at smaller cost and with greater speed than by ordinary methods, which in the case of the Cameroons would require a considerable outlay.

SHORE SIGNALS

In order that operations at sea may be carried out, intermediate signals (stakes or markers) must be set up at the rate of one per mile between the pyramids, if work is done on the scale of 1/25,000, which is the scale generally adopted for coastal surveying in the colonies.

These signals may first be sighted from the adjacent pyramids, then from stations at sea such as B_n by measuring the angles between the signals and one of the pyramids taken as reference, with a hydrographic circle from the anchored vessel. The angles on the signals should be sighted by observers stationed as near as possible to the mast at the identical moment the flag is lowered. The sighted targets are not more than 10 kilometres away, and with careful adjustment of the circles by taking a series of left-hand and right-hand points in the circle so as to eliminate collimating error, measurements of the angles to within 2' can be expected, supplying a degree of accuracy of 5 or 6 metres with respect to the intermediate signal's position, an adequate amount in the case of signals to be plotted on a 1/25,000 projection.

REMARK CONCERNING COMPUTATION OF TRAVERSE IN RECTANGULAR CO-ORDINATES

Observed azimuth will have to be corrected for meridian convergence with regard to the projection used (Gauss projection of National Geographical Institute in case of Cameroons). The length computed will also have to be subjected to linear correction for curvature of the earth before it may be used in computing the traverse in rectangular co-ordinates.

NOTE. — If 4 Wild theodolites are available, measurement of the base at every other signal will suffice.