USE OF RAYDIST SYSTEM IN PORTUGUESE GUINEA SURVEY

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As a prerequisite to the construction of Chart No. 214 covering the entrance to Geba Channel between Caio and Caravela Island, the lower part of the Rio Grande and a stretch of sea approximately 25 miles long west of Caio, and thus consisting of an extremely important navigational area for making a land-fall in Guinea, the officer in charge of operations was faced with the task of carrying out a hydrographic survey of the area.

Three methods were available for fixing the position of the vessel offshore and within the area of sounding :

a) *Navigation by D.R.*, by which the vessel's position could be obtained in terms of the course and speed, due account being taken of wind and current.

This method, which is especially inaccurate in areas affected by strong currents, could not be considered, since an exact survey was required.

b) *Lines of anchored buoys*, placed approximately 5 miles apart, i.e. at intervals at which they would be visible for obtaining bearings from the vessel and consequently the vessel's position.

The first row of buoys would in this case be determined from positions ashore and the others anchored according to sextant angles obtained from buoys in the initial row.

This method, which had been tried out during the 1951-1952 expedition, gave no results, as the signals could not be anchored or kept in place owing to the action of wind and currents.

Satisfactory results could only be obtained following the acquisition of appropriate equipment, which would be nearly as expensive as electronic equipment.

Moreover, besides being a great deal slower, this system has the disadvantage of considerably increasing the error in the case of the buoy lines farthest from shore.

c) *Electronic methods,* which at the present time enable positions to be determined with great accuracy, and which actually was best suited for the purposes of Chart No. 214.

The problem arose of making a selection from among the various existing systems.

The officer-in-charge, in view of the expense involved in the purchase of such equipment and on the basis of previous investigation, chose the Raydist System, which had already been tested with excellent results by a Portuguese survey group, the Mozambique Hydrographic Survey.

RAYDIST SYSTEM

The Raydist system purchased for the Survey, known as the N-type system, essentially consists of a two-dimensional system of hyperbolic navigation radiating continuous waves and which can be used simultaneously by several ships. It is one of several radio position-fixing systems built by the Hastings Instrument Company of Hampton, Virginia.

These systems, which are extremely flexible, can be adapted to various uses, from simple systems for speed and distance determination to hyperbolic and elliptical systems for marine and air navigation.

All are based on the principle of phase comparison of audible signals, obtained by heterodyning continuous wave signals radiated by transmitters on frequencies several hundred cycles apart.

The number and orientation of the transmitters and receivers vary according to the specific type of application desired.

Description of system used by Guinea survey

The system used is of the N type, as previously mentioned, and consists of the following features :

Three continuous-wawe stations, transmitting on frequencies 1742 Kc/s, 1742.210 Kc/s and 1742.370 Kc/s.

Each station includes :

(1) A continuous-wave transmitter;
(2) An aerial coupling unit;
(3) A transmitting aerial (consisting of a metal tower 30 metres high).

The station is powered by a 750-watt mobile gasoline-operated unit.

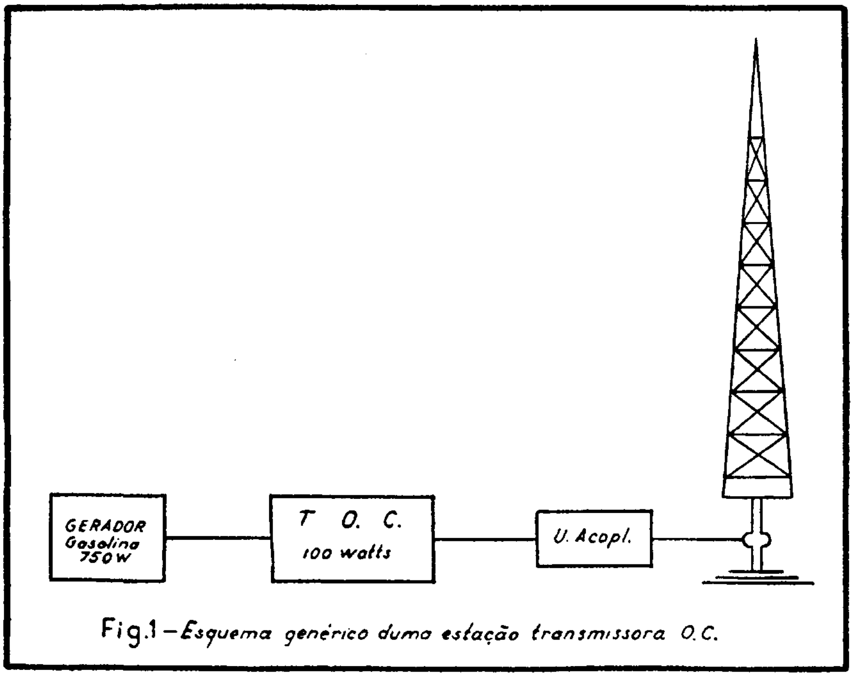

Fig. 1.
Block diagram of CW transmitting station.

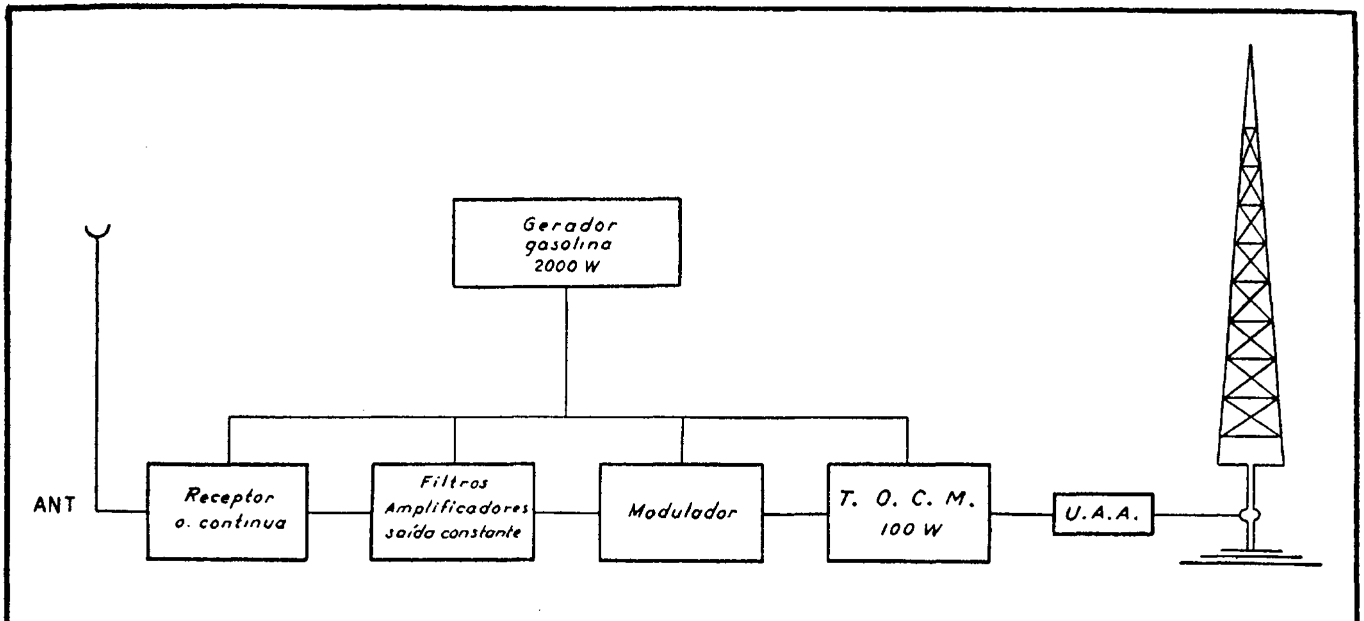

Fig.2

Esquema genérico da estação de referencia

Fig. 2.

Block diagram of reference station.

The station is powered by a 2000-watt mobile gasoline-operated unit.

A *reference station*, consisting of :

(1) A receiving aerial;
(2) A CW receiver tuned on 1742 Kc/s;
(3) A filter and amplifier system of constant output;
(4) A modulator;
(5) A continuous modulated wave transmitter, transmitting on 2398 Kc/s;
(6) An aerial coupling unit;
(7) A transmitting aerial (consisting of a metal tower 30 metres high).

A *master station*, which is shipborne, and consists of :

(1) A receiving aerial;
(2) A CW receiver tuned on 1742 Kc/s;
(3) A continuous modulated wave receiver tuned on 2398 Kc/s;
(4) A filter system;
(5) Amplifiers of constant output;
(6) A monitoring system;
(7) Phasemeter amplifiers;
(8) Phasemeters.

INSTALLATION AND OPERATION OF SYSTEM

Each transmitting station is set up on shore at positions determined beforehand.

The reference or relay station is also shore based, but there is no necessity in fixing its position, the only requirement being that its distance from each of the transmitting stations be such as to cause no interference.

The master station is shipborne, and is therefore the only mobile part of the equipment.

The ship's position is accurately determined by comparing the relative phase of the audible signals obtained by heterodyning the signals received directly from the transmitting stations and those retransmitted by the reference station.

The phase differences obtained at the master station are a function of the parameters in the system and of the differences in the distance of the ship (master station) from the transmitting stations.

As the system's parameters are constant, the difference in phase is solely dependent on the distance differences, and their loci are hyperbolae.

This can be proved by a mathematical analysis of events occurring at a given instant with respect to one half of the system.

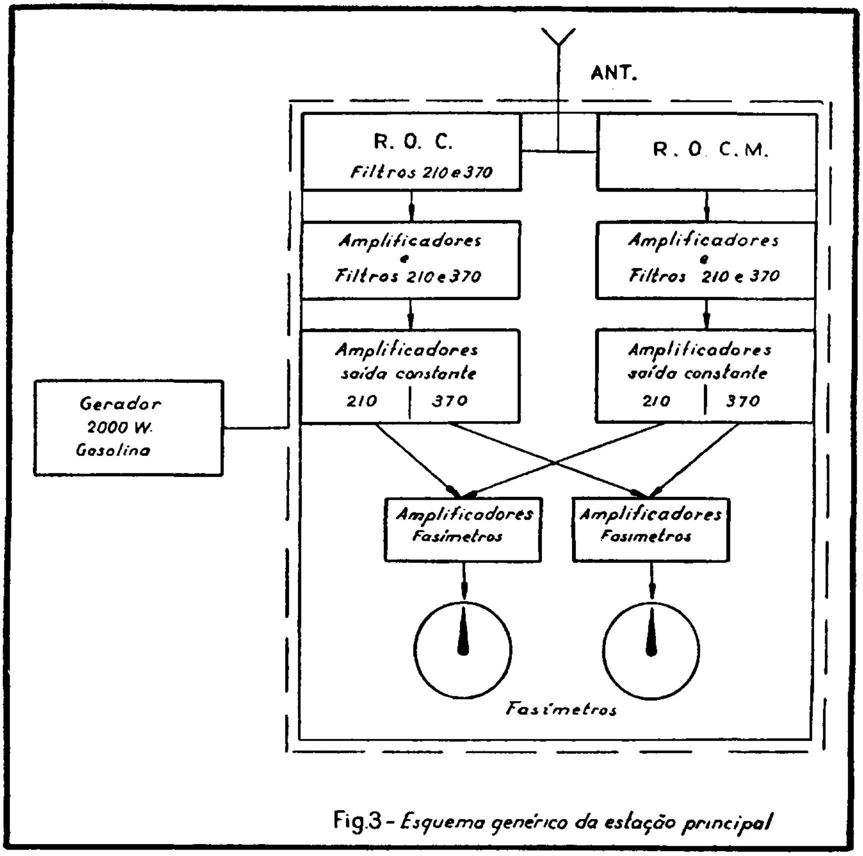

Fig. 3.

Block diagram of master station.

The station is powered by a 2000-watt mobile gasoline-operated unit.

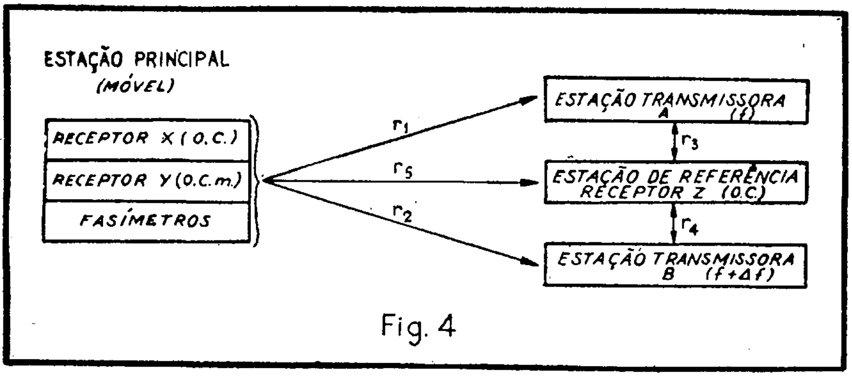

Fig. 4.

Figure 4 shows that a signal leaving transmitter A, operating on frequency f, travels along distance r_1 to receiver X (the CW receiver) at the master station. It is then heterodyned by another signal transmitted along distance r_2 by transmitter B operating on frequency $f + \Delta f$.

These signals are propagated simultaneously along r_3 and r_4, are received and heterodyned by the receiver Z at the reference station, and are then retransmitted along r_5 to receiver Y (the modulated CW receiver) at the master station.

The signals received at the X and Y receivers at the master station are sent together to the phasemeters, in which the phase difference is measured.

If we consider the system at a given instant and designate the phases of the signals transmitted from A and B as O_A and O_B, we know that the phases of signals at receiver X are given by the following expressions :

$$\theta_{AX} = \theta_A - \frac{2\pi f}{c}(r_1) - \phi\,(r_1)$$

$$\theta_{BX} = \theta_B - \frac{2\pi(f + \Delta f)}{c}(r_2) - \phi\,(r_2)$$

where c represents the velocity of propagation of the radio signals, and $\phi\,(r_1)$ and $\phi\,(r_2)$ the phase variations to which the signals are subjected owing to surface wave attenuation along paths r_1 and r_2.

Owing to the heterodyning of these two signals, we get a signal of phase α X, supplied by the following expression :

$$\alpha_X = \theta_{BX} - \theta_{AX} = \theta_B - \theta_A - \frac{2\pi(f + \Delta f)}{c}(r_2) + \frac{2\pi f}{c}(r_1) + \phi(r_1) - \phi(r_2)$$

With respect to receiver Z at the reference station, the same process occurs, the phases being :

$$\theta_{AZ} = \theta_A - \frac{2\pi f}{c}(r_3) - \phi(r_3)$$

$$\theta_{BZ} = \theta_B - \frac{2\pi(f + \Delta f)}{c}(r_4) - \phi_4)$$

and the phase of the heterodyned signal being :

$$\alpha_Z = \theta_{BZ} - \theta_{AZ} = \theta_B - \theta_A - \frac{2\pi(f + \Delta f)}{c}(r_4) + \frac{2\pi f}{c}(r_3) + \phi(r_3) - \phi(r_4)$$

The heterodyned signal at the reference station is then sent on to the master station and is received at receiver Y.

In view of the foregoing, the phase of the signal received at Y is given by :

$$\alpha_Y = \alpha_Z - \frac{2\pi \Delta f}{c}(r_5) - \phi(r_5)$$

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Page 16 - line 11, should read:

...from A and B as θ_A and θ_B, we know... etc.

Page 16 - line 7 from bottom, should read:

$$\theta_{BZ} = \theta_B - \frac{2\pi\ (f+\Delta f)}{c}(r_4) - \varphi(r_4)$$

Page 17 - third line, should read:

$$\alpha_Y = \theta_B - \theta_A - \frac{2\pi\ (f+\Delta f)}{c}(r_4) + \dots \text{ etc.}$$

Page 17 - line 7, should read:

$$\psi = \alpha_Y - \alpha_X = \theta_B - \theta_A - \frac{2\pi\ (f+\Delta f)}{c}(r_4) + \frac{2\pi f}{c}(r_3) + \varphi(r_3) - \varphi(r_4)\dots \text{ etc.}$$

Page 17 - line 9 from bottom, should read;

...while r_1, r_2 and r_5 are variable;

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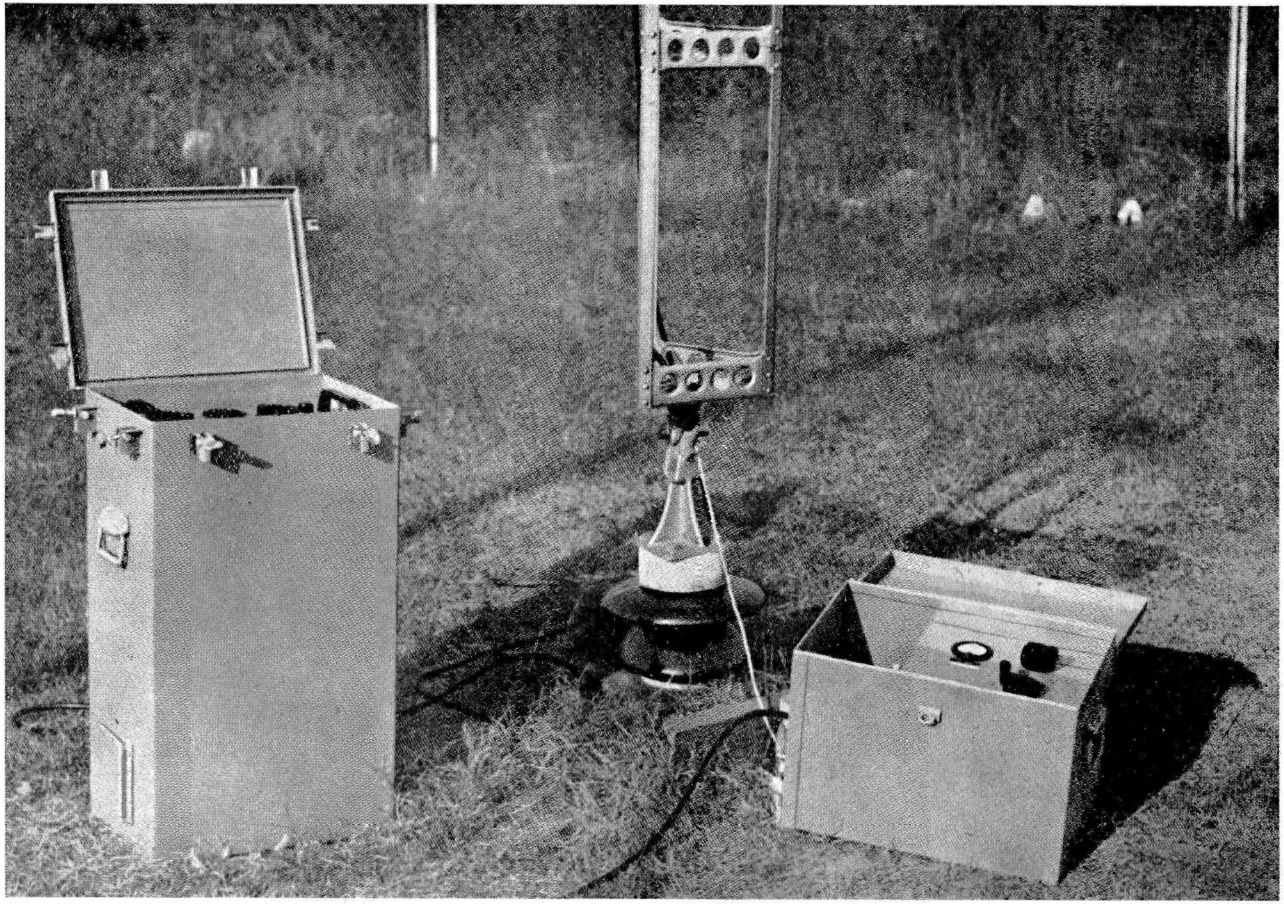
Revue Hydrographique Internationale

Volume XXXI, N° 2, Novembre 1954

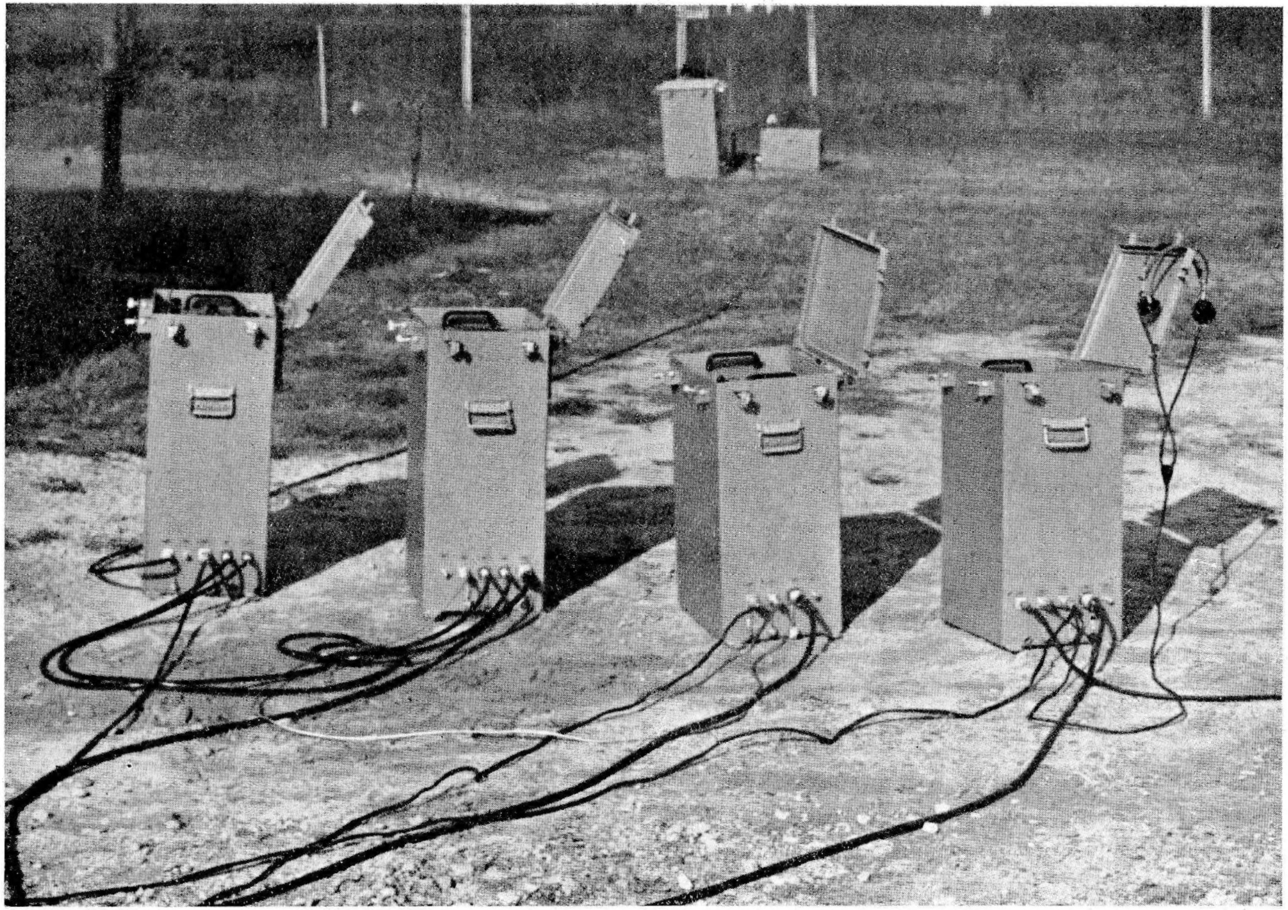
LE SYSTÈME RAYDIST DANS L'HYDROGRAPHIE DE LA GUINÉE

Page 17, ligne 12, lire:

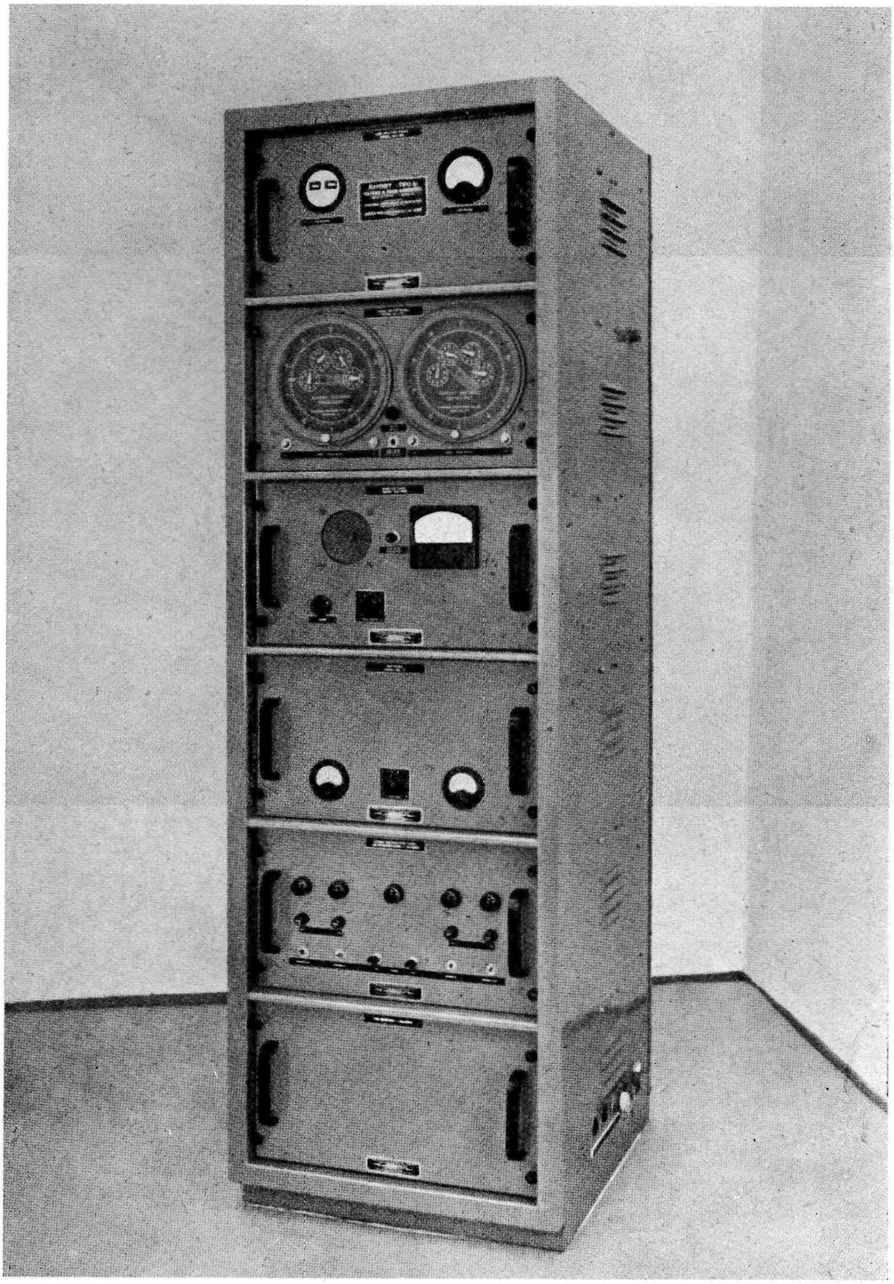
$$\psi = \alpha_Y - \alpha_X = \theta_B - \theta_A - \frac{2\pi\ (f+\Delta f)}{c}(r_4) + \frac{2\pi f}{c}(r_3) + \varphi(r_3) - \varphi\ (r_4)\dots \text{ etc.}$$



Short wave Transmitting Station.



Reference Station.



Master Station.

Δf being taken as the frequency of the signal. By substituting the value of αZ we get :

$$\alpha_Y = \theta_B - \theta_A - \frac{2(f+\Delta f)\ \pi}{c}(r_4) + \frac{2\pi f}{c}(r_3) + \phi(r_3) - \phi(r_4) - \frac{2\pi\Delta f}{c}(r_5) - \phi(r_5)$$

The signals of phases α_X and α_Y are then sent to the phasemeter where they are compared, and a phase difference ψ is finally obtained, supplied by the formula :

$$\psi = \alpha_Y - \alpha_X = \theta_B - \theta_A - \frac{2\pi(f+\Delta f)}{c}(r_4) + \frac{2f}{c}(r_3) + \phi(r_3) - \phi(r_4)$$
$$- \frac{2\pi\Delta f}{c}(r_5) - \phi(r_5) - \theta_B + \theta_A + \frac{2\pi(f+\Delta f)}{c}(r_2) - \frac{2\pi f}{c}(r_1) - \phi(r_1) + \phi(r_2)$$

By simplifying and regrouping the terms, we get :

$$\psi = \frac{2\pi f}{c}(r_2 - r_1) + \frac{2\pi\Delta f}{c}(r_2 - r_5) - \phi(r_1) + \phi(r_2) - \phi(r_5) + \frac{2\pi f}{c}(r_3 - r_4)$$
$$- \frac{2\pi\Delta f}{c}(r_4) + \phi(r_3) - \phi(r_4)$$

Before continuing the analysis of this expression, it will be seen that ψ is independent of the initial phases θ_A and θ_B, which shows that the stations in the system can be operated independently without regard to synchronization, an obvious advantage of the Raydist system as compared to other radio position-fixing systems.

Since we know that transmitters A and B and the reference station are in fixed positions, it can be shown that r_3 and r_4 are constant while r_1, r_2 and r_5 are variable; therefore, by grouping the constant terms in the previous expression and considering them as equivalent to a constant K,

$$K = \frac{2\pi f}{c}(r_3 - r_4) - \frac{2\pi\Delta f}{c}(r_4) + \phi(r_3) - \phi(r_4)$$

for ψ we get the following expression :

$$\psi = \frac{2\pi f}{c}(r_2 - r_1) + \frac{2\pi\Delta f}{c}(r_2 - r_5) - \phi(r_1) + \phi(r_2) - \phi(r_5) + K$$

The phase variations ϕ (r) are extremely small and are barely worth considering even for purposes of a high degree of accuracy, so that, by neglecting them, we get :

$$\psi = \frac{2\pi f}{c}(r_2 - r_1) + \frac{2\pi\Delta f}{c}(r_2 - r_5) + K$$

As moreover Δf is very small as compared with f, its effect is slight; and since a phase variation at a frequency on the order of 100 c/s is small and may be neglected, the expression obtained for the final phase is given by :

$$\psi = \frac{2\pi f}{c}(r_2 - r_1) + K$$

This equation shows that angle ψ is independent of the position of the reference station, and subject only to the ship's position in relation to the transmitting stations.

It will moreover be seen that angle ψ is constant for all points where the difference $(r_2 - r_1)$ is constant, i.e. that the loci of the system are homofocal hyperbolae with their foci at A and B.

Computation of the system is therefore solely based on the distance between stations A and B and on the frequency f of the system.

The process occurring in the half of the system consisting of stations A and B is likewise true for the half consisting of stations A and C, and we thus have two angles with phase differences of ψ_1 and ψ_2, corresponding to each pair of stations and supplying the coordinates of the mobile station (the ship) in a double hyperbolic pattern in which stations A, B and C are the foci.

Figure 5 illustrates this arrangement.

OPERATIONAL PRINCIPLES OF VARIOUS PARTS OF SYSTEM

a) *Transmitting stations*

The transmitting stations consist of 100-watt continuous-wave transmitters, controlled by a highly stable crystal radiating continuous-wave signals through space at frequencies 1742 Kc/s, 1742.210 Kc/s, and 1742.370 Kc/s.

b) *Reference station*

This station, through the medium of a crystal-controlled receiver tuned to the radiation frequency of the CW transmitters, receives the signals, which are heterodyned, and by combination of the 3 frequencies and filtering, two low-frequency signals are obtained: one of 370 c/s and another of 210 c/s. These signals (which are audible), after being amplified, pass through constant output amplifiers which maintain the signals at a constant level regardless of fluctuations, and thence through a modulator unit are used for the frequency modulation of the 100-watt transmitter of the station, whose carrier wave operates on 2398 Kc/s.

c) *Master station*

There are two receivers at this station.

One of these is tuned to the frequency of the CW transmitters and receives the transmitting station signals, which after being heterodyned and filtered as in the case of the reference station supply the two audible signals of 210 and 370 c/s.

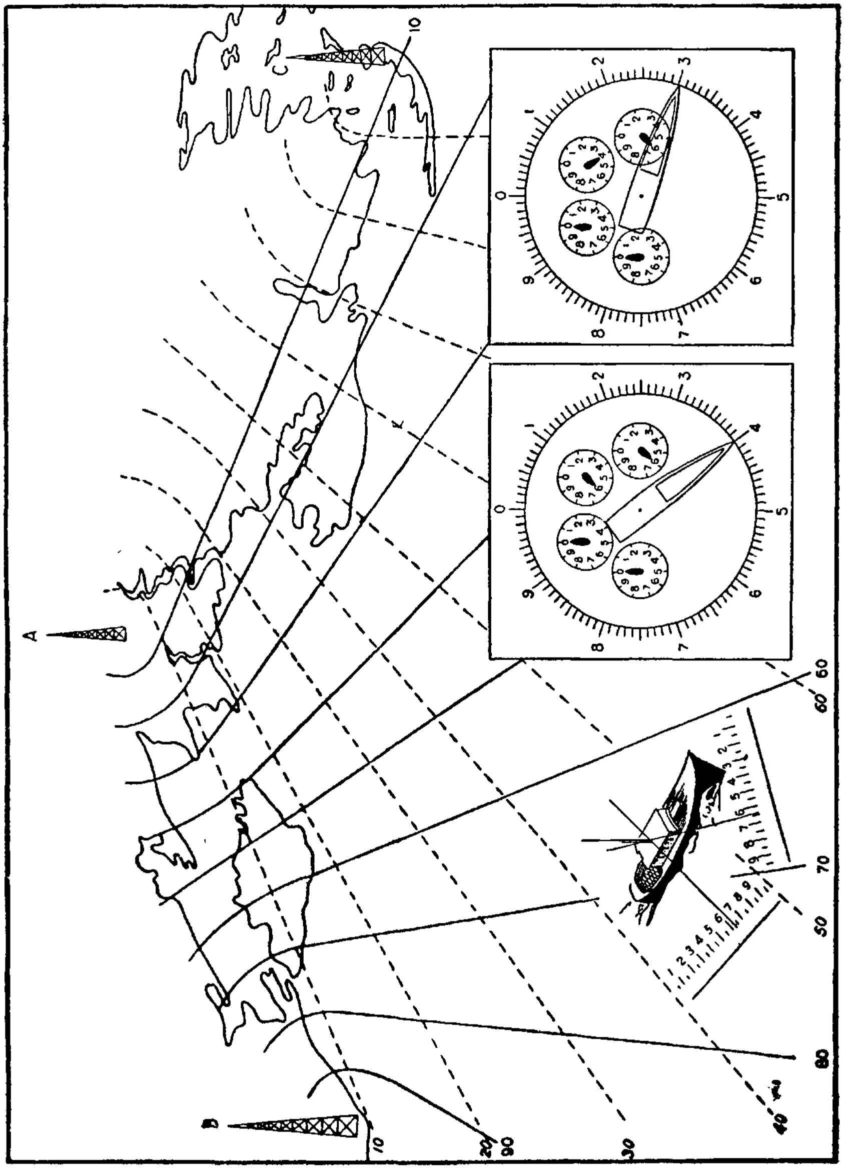


Fig. 5.

The other is tuned to the frequency of the reference station transmitter, and as soon as the modulated frequency signal is received, it demodulates the latter, thereby supplying the signals at frequencies of 210 and 370 c/s.

Two sets of signals of 210 and 370 c/s are thus obtained, one relating to the reception of the directly transmitted signals, and the other to reception of the signals retransmitted by the reference station.

These signals are thereupon amplified and refiltered for greater purity and in order to eliminate any others that may have penetrated during the initial filtering operation.

They are then taken through the constant output amplifiers, which maintain them at constant strength regardless of fluctuations due to variations in the distance from the CW transmitters, and then proceed to the phasemeter amplifiers, which provide the signal strength required for adequate operation.

From there, the signals pass to each of the phasemeters, where the phases of each pair of signals of equivalent frequency are compared, one being applied to the respective rotor and the other to the stator.

The phasemeters are the most important and delicate units of the entire equipment, and are responsible for its applicability. It may therefore be well to attempt to describe as clearly and as briefly as possible how they operate.

It is apparent from the foregoing that measurement of the phase difference between the two 210-c/s signals and two 370-c/s signals received on board will occur in the phasemeters.

We know that when we have two radio waves of equivalent frequency, if they are in phase no current is generated; but if they are not in phase (see Fig. 6), a current will be produced whose strength increases with the difference in phase between the two signals.

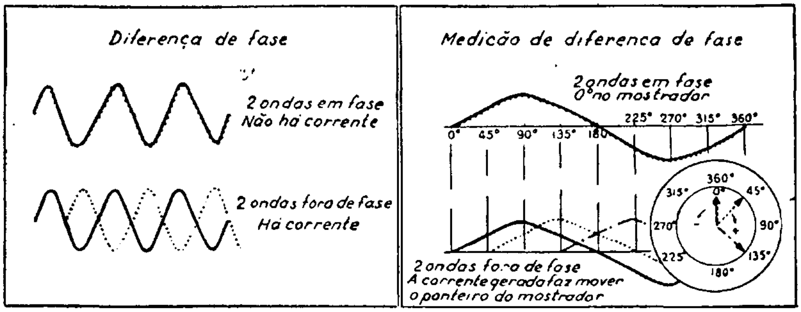


Fig. 6

This principle is applied to the phasemeters, where the current is used to actuate a motor consisting of two windings : one fixed — the stator — to which one of the signals is applied, and the other mobile — the rotor — to which the other is applied.

The windings tend to remain in a balanced position, so that when the two waves are in phase, the rotor does not move; but when they are out of phase, the generated current tends to rotate the rotor, which will move a new balanced position is reached.

By gearing the rotor to a pointer on a dial, the pointer will move with the rotor, and by means of suitable graduations will show the phase difference between the two signals.

The shipborne phasemeters do not show the ψ phase difference as in the preceding figure, but the value $\frac{\psi}{2\pi}$, i.e. circles and fractions of a circle.

So that by again taking the final equation relating to each pair of stations in the system :

$$\psi = \frac{2\pi f}{c}(r_2 - r_1) + K$$

And dividing by 2π:

$$\frac{\psi}{2\pi} = \frac{f}{c}(r_2 - r_1) + K'$$

with $c = \lambda f$, where λ is the wave length, we get :

$$\frac{\psi}{2\pi} = \frac{1}{\lambda}(r_2 - r_1) + K'$$

To each value of $(r_2 - r_1)$ corresponds a position line, and if we designate each $\frac{\psi}{2\pi}$ reading of the phasemeter as H, we get :

$$H = \frac{r_2 - r_1}{\lambda} + K'$$

Let us now consider two concentric lines of position with values of ψ other than 2π or values of H other than 1, and let us call the area between these two position lines a « hyperbolic lane ». It can readily be seen that the length intercepted on the base line by the lane is equivalent to $\frac{\lambda}{2}$ (one half wavelength).

Let us then consider Figure 7, in which points 1 and 2 differ by $\frac{\lambda}{2}$.

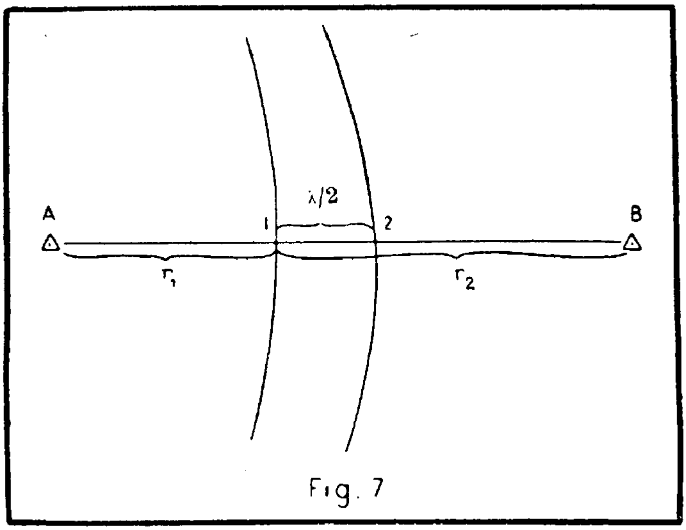


Fig. 7

At points 1 and 2 we get :

$$H_1 = \frac{r_2 - r_1}{\lambda} + K'$$

$$H_2 = \frac{\left(r_2 - \frac{\lambda}{2}\right) - \left(r_1 + \frac{\lambda}{2}\right)}{\lambda} + K'$$

whence $H_1 - H_2 = 1$, which proves our assumption.

It can then be shown that each rotation of the phasemeters corresponds to a hyperbolic lane, and as the dial is divided into hundredths, interpolations can be made with the desired accuracy and as the scale of the chart permits.

The phasemeters are moreover equipped with a device which counts the number of lanes travelled with respect to a given origin.

The monitoring unit at the master station should likewise be considered; it enables each of the 210-c/s and 370-c/s signals to be heard and the frequency to be measured, thereby supplying valuable information regarding the operation of the transmitting and reference stations.

UTILIZATION OF SYSTEM

In addition to the operations of a technical nature necessary for working the equipment, its initial utilization requires perfect tuning of the continuous-wave transmitters in order that maximum purity of the audible 210 and 370-c/s signals may be obtained.

It then becomes necessary to determine the wavelength value, which has been stated as being dependent on the frequency of transmission and velocity of propagation of electromagnetic waves, with respect to the area in which work is to be carried out.

The frequency can accurately be determined by using wavemeters.

Velocity of propagation, however, is another matter, since it is dependent, among other things, on such local factors as pressure, temperature and humidity.

In this connection, following a certain amount of research and experiment, scientists have now obtained uniform values for the velocity of propagation of electromagnetic waves through space in various parts of the world, and have determined its variation in terms of the factors mentioned above, with the result that whenever such factors are available, a value can be assigned to the velocity of propagation which will meet the accuracy requirements for work undertaken with such equipment.

Where the atmospheric characteristics are inadequately known, the system itself enables accurate determination of the wavelength value.

For this purpose two continuous-wave transmitters need only be set up in positions whose coordinates have been defined with absolute accuracy, so that the geodetic distance between them is known, and the mobile station so shifted in position that both stations are included in its coverage, as shown in Figure 8.

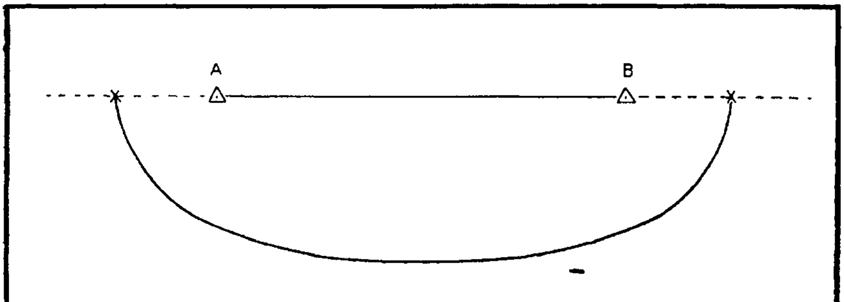


Fig. 8

By taking phasemeter readings when crossing the extension of the line joining both stations, we get the total number of hyperbolic lanes and fractions of a lane between the two positions.

Since the width of each lane corresponds to one-half wavelength, the latter can readily be determined, given the distance AB.

Use can also be made of the opposite condition, consisting in the determination of the length AB given the wavelength.

The base line extension cannot be crossed in the immediate vicinity of the stations, owing to the necessity of avoiding induction phenomena that might adversely affect results, and use of the method is therefore occasionally difficult.

Once the wavelength is known, the charts should be overlaid with the hyperbolic pattern.

In the case of surface navigation, a two-dimensional pattern can be plotted, and any type of projection can be used following the computation of the hyperbolic pattern on the ellipsoid and its transference point by point to the chart on the desired projection.

Since the computing of the pattern on the ellipsoid is a fairly complex process, the difficulty is removed by effecting the computations on the sphere instead of the ellipsoid.

However, even this method is a laborious one, and the large amount of time and effort expended is only justifiable in the case of computations required by such fixed or long-range navigational aids as the Loran system in America or the British Decca system.

As regards limited areas of operation, it will readily be apparent that a tangent plane can be substituted for the surface of the ellipsoid and the hyperbolic pattern computed on the plane, which involves a much simpler and more rapid process.

Where the scale of the chart permits, moreover, a graphical plot can be substituted, which will be described, since this was the method used.

In our case the chart scale was such as to include the positions of the three transmitting stations and therefore the foci of the two families of hyperbolae.

Actually, a graphical plot can likewise be made when charts of a larger scale are used and the positions of the stations do not appear on the chart, provided sufficient space and the necessary drawing instruments are available for plotting the relative positions to scale.

After the hyperbolic pattern has been plotted, two methods can be followed in laying out the pattern for operational purposes, according to the preferred system of numbering.

The system used by us will first be described, consisting of a pattern with numbers beginning at the foci, as shown in Figure 9.

In this case the base line and base line extensions are divided, beginning at the focus which is taken as the origin, the latter normally being the one corresponding to the centre station (F_0 in the figure), into parts proportional to the wavelength or multiples thereof, according to the scale used and the density required for the pattern.

Then by taking foci F_0 and F_1 as the centre points and the distances to the various base line divisions as radii, circles are drawn.

The base line points are numbered by assigning to them the corresponding multiples of λ, which are taken as positive on the base line side and negative on the other.

The hyperbolae are then plotted by drawing them through the points where the circles intersect, in such a way that the sum of their numbers, corresponding to the hyperbola number, retains a given constant value.

Since this numbering process is somewhat arduous, another more expeditious method is used in which the numbering of the circles is avoided and the hyperbolae are plotted by taking the hyperbolic arc between two consecutive intersections of the circles as the diagonal of the diamond-like figure formed by the intersections.

An additional system consists in numbering the hyperbolic pattern from the base line axis, using positive numbers on the side towards the end station and negative numbers on the side towards the centre station.

The plotting process is the same, the only difference consisting in the numbering along the base line, which is initiated from the axis.

Figure 10 illustrates an instance of this method.

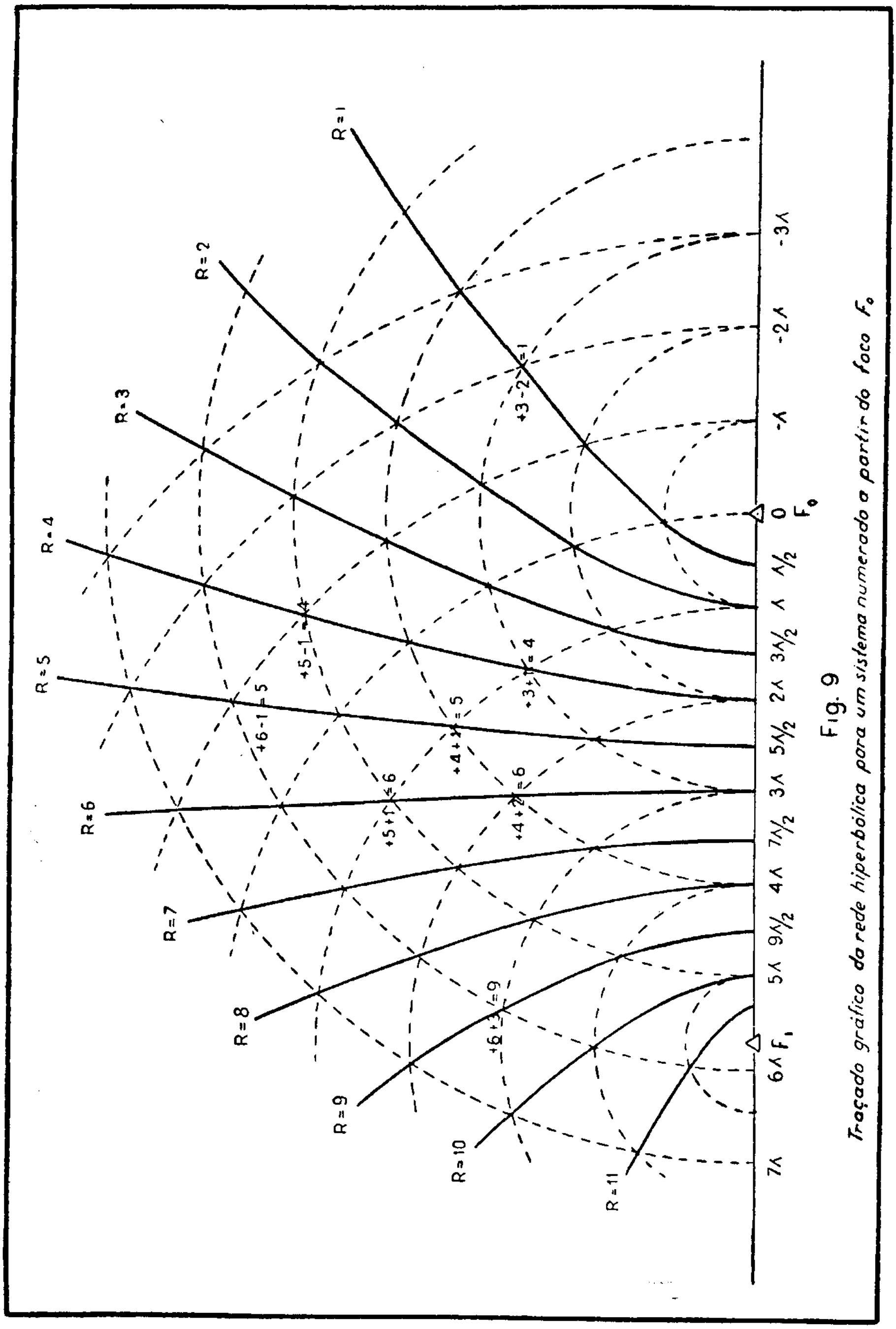


Fig. 9

Traçado gráfico da rede hiperbólica para um sistema numerado a partir do foco F_0

Fig. 9.

Graphical plot of hyperbolic pattern for system numbered from focus F_0.

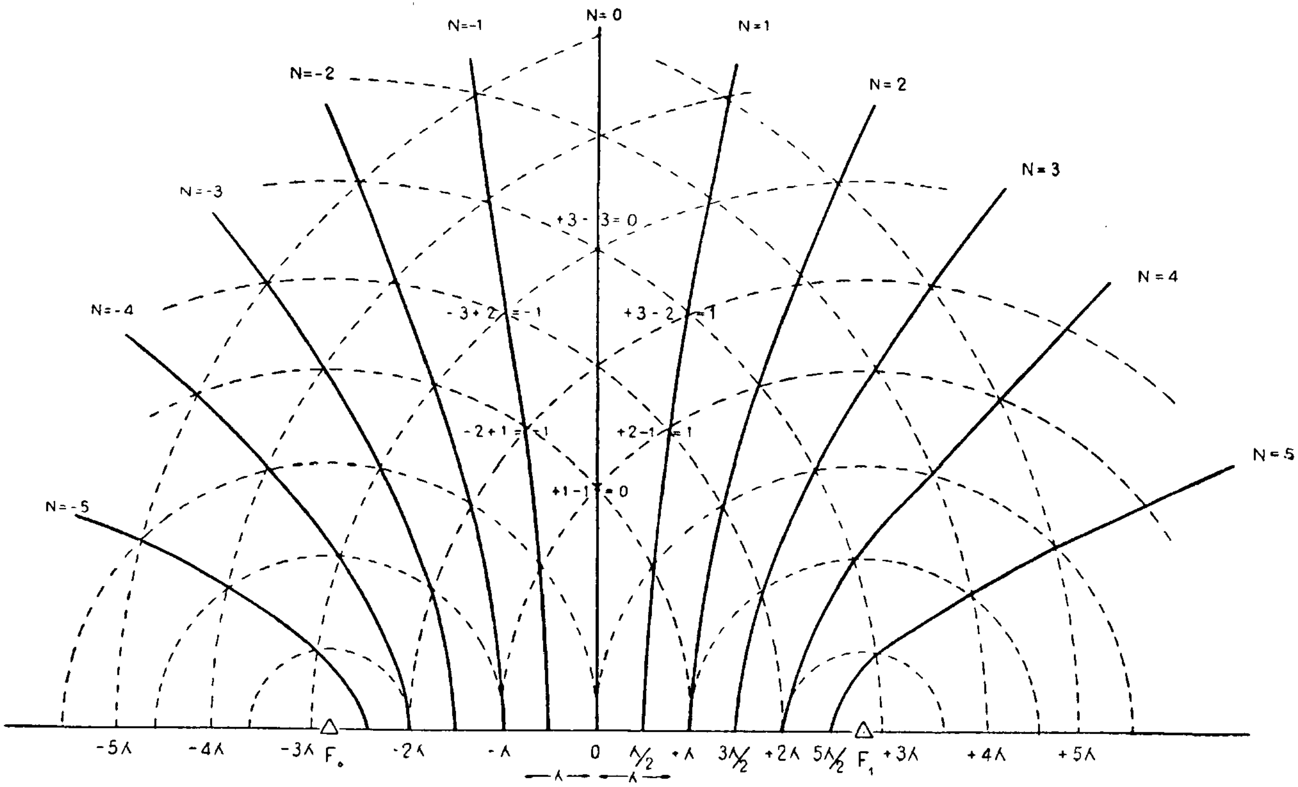


Fig 10

Traçado gráfico de uma rede hiperbólica para um sistema numerado a partir do eixo (Divisão da base a partir do eixo)

Fig. 10.

Graphical plot of hyperbolic pattern for system numbered from axis (Division of base line from axis).

Before completing the discussion relating to the system's utilization, adjustment operations must be mentioned. These must be carried out as soon as work is begun, and when soundings are obtained, which were the purpose of our survey.

Adjustment of the system includes the checking of the direction of rotation of the phasemeters, as the phasemeter readings must vary in the same direction as the numbers of the hyperbolic pattern plotted on the chart.

This operation was unnecessary in our case, as we had selected the first type of pattern illustrated herein, numbered in accordance with the direction of phasemeter rotation.

Otherwise, when it is found that the direction of rotation is reversed, the operation consists in interchanging the signals applied to the rotor and stator.

Another adjustment that was carried out daily, in view of the fact that the system supplies no absolute indications, consists in the precise determination by horizontal angles (obtained through sextant and station pointer observations) of a position of the ship, which is plotted on the chart, and in obtaining the corresponding hyperbolic coordinate readings which are applied to the phasemeters. The latter from then on will automatically and continuously supply the position of the mobile station within the hyperbolic pattern.

In carrying out sounding operations, two types of spacing may be used as shown in Figures 11 and 12.

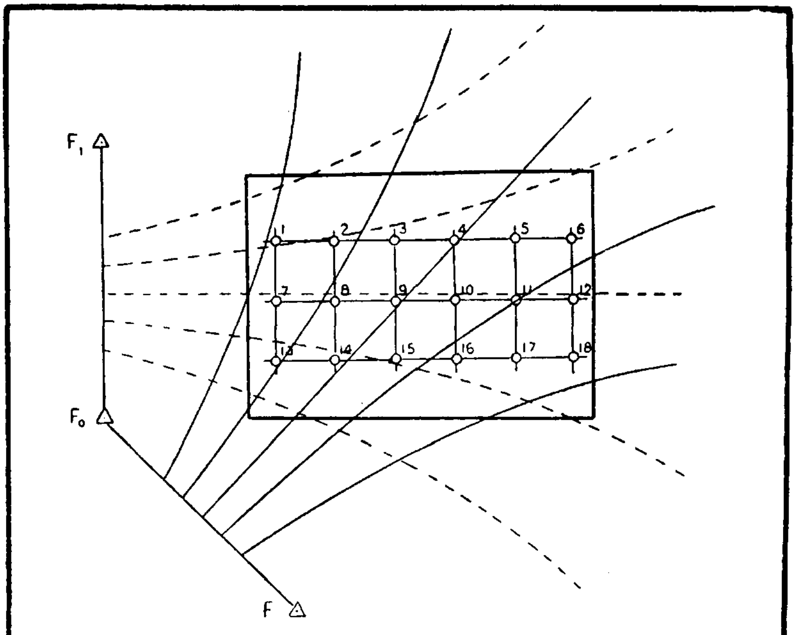


Fig. 11

Distribuição rectilinea

Fig. 11.

Rectilinear distribution.

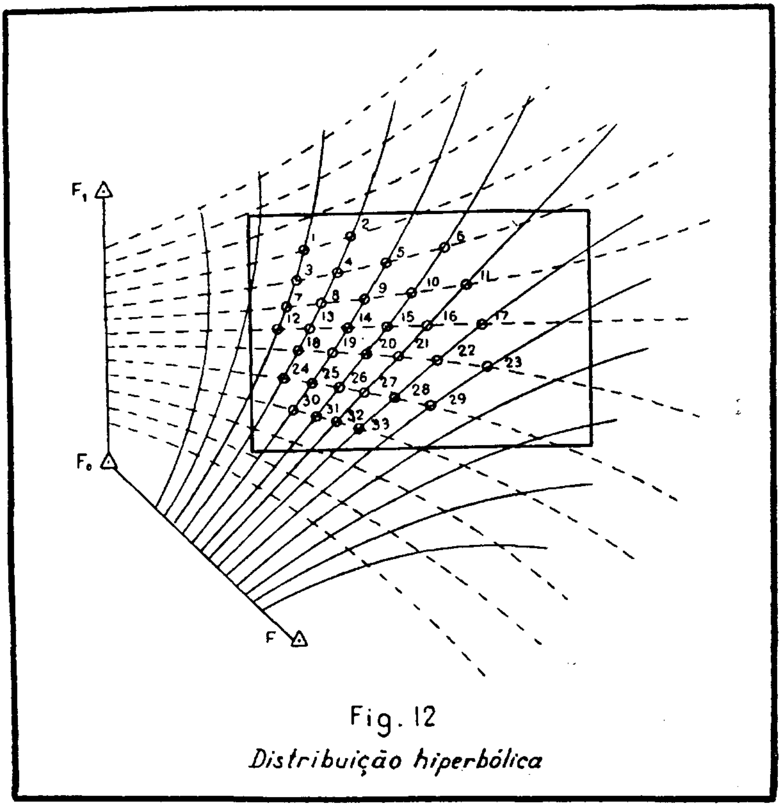


Fig. 12.

Hyperbolic distribution.

As a rectilinear system of distribution of soundings is used for our charting purposes, known as a « grid », a plot of the sounding pattern need only be drawn on the chart overlaid with the hyperbolic pattern, consisting of a series of straight lines directed NS and EW, and spaced a suitable distance apart.

The value of the hyperbolic coordinates for each sounding as defined by the grid intersections must thereupon be determined and tabulated.

Since accurate and instantaneous indications are continuously supplied by the system, it is easy to navigate along a given sounding line and to correct the ship's course with the care desired in order to pass over each sounding position.

The sounding apparatus is operated continuously in order that the bottom profile may be obtained along the line of sounding, and at each grid position, a record is made of the time, number of sounding, the depth encountered, and the nature of the bottom, the latter being obtained with a « Bagre » instrument.

During the sounding operations carried out in Guinea waters, the Survey prior to the receipt of Raydist used two types of sounding : the grid method and the echo-sounding run method.

In the first method, the sounding-boat's position is determined by two horizontal sextant angles between three hydrographic signals ; inshore, when the three hydrographic signals cannot be observed, a fix is obtained by the distance and azimuth of a single hydrographic signal.

When the grid method of sounding is used on the basis of hydrographic signals, the boat is stopped as soon as the position is reached and the depth has been indicated by the sounding apparatus. A bottom sample is then taken with a sounding lead.

Bottom samples are obviously not obtained in the exact locations as determined by the hydrographic signals, owing to the drifting of the ship or craft. However, this is of no particular significance, as the depth supplied by the echo-sounding apparatus has been obtained in the correct position.

The fact that the ship must be stopped in order that the bottom samples may be collected is not detrimental, since in this method of sounding the constant maneuvering of the ship in order to meet the sounding angle requirements does not enable the courses followed to be determined.

Owing to these conditions, the utmost advantage is not taken of the information supplied by the echo-sounding apparatus, which is only possible when definite courses are followed and changes can be controlled with certainty.

This latter method is used in the sounding process known as the « echo-sounding run » method, in which the origin of each run is determined by sextant, as in the grid system.

Control positions are determined by sextant observations of angles between hydrographic signals.

These positions are immediately laid out on the plotting sheets and the necessary course changes indicated. At the time of changing course, a control point is invariably determined. The echo-sounding run method locates the bottom profiles, which in addition to other advantages enables a bathymetric record to be obtained.

Raydist not only enables sounding beyond the visual range of the hydrographic signals, but a single type of sounding operation to be carried out, since the phasemeters supply a continuous indication of the vessel's position and therefore enable the course to be adjusted in such a way that the grid lines are followed continuously, while moreover coinciding with the echo-sounding runs.

Reference has been made to the necessity of stopping in order to collect the bottom samples. This difficulty was overcome by Lieutenant Manuel Lopes de Mendonça, who designed a sounding lead which enabled bottom sampling to be carried out while under way. This device was called a « Bagre », owing to its resemblance to a widely prevailing type of fish of the same name found in the rivers of Guinea. During the 1952-1953 season, the Bagre instrument proved to be completely successful at speeds up to 8 knots and depths up to 30 metres, or the maximum values attained during these particular operations.

Through the joint use of Raydist, echo-sounding apparatus and the Bagre instrument, maximum results were therefore obtained from the sounding operations.

WORK CARRIED OUT

The Raydist equipment at present operated by the Guinea Survey was received at Bissau in mid-December 1952, and was set up, checked and calibrated during the same month at Caiô.

The station sites had been selected beforehand from among the few locations providing facilities for landing the equipment and the supplies for the staff, while meeting all requirements that would ensure maximum operational efficiency.

The sites for the transmitting stations were chosen at the following points : the bluff on the beach at Varela, the western extremity of Pelindà Island, and the northwestern point of Caravela Island.

These three locations not only provided adequate coverage for the area to be surveyed for the purposes of Chart No. 214, but also enabled the angles of intersection of the position lines to fall within the limits of 30° and 150°. The choice was therefore a happy one, and in the majority of locations the most favourable conditions of intersection were met with, i.e. in the neighbourhood of 90°.

Sites were moreover chosen overlooking the sea, so that the electromagnetic waves would be propagated directly over the water, as propagation over land causes absorption and deviations, due to the obstacles that normally prevail.

Elevations of the land are no great impediment in Portuguese Guinea, but the densely wooded areas would have been responsible for a large amount of absorption if they had been disregarded.

In view of the conditions described above, the islet of Caio was chosen as the site for the reference station.

Since this was a central location in the area to be surveyed, and was easy to land upon, assistance could be rendered with greater speed and efficiency to the relay station, which is more apt to break down than the transmitting stations, since the latter's equipment consists only of the CW transmitters.

The stations were set up at the selected sites immediately following Christmas. Their geographical coordinates had been computed previously.

The Raydist chart was then constructed and drawn on board ship. Sounding operations were begun during the second week in January, the Raydist system being relied upon for navigation and position-fixing.

The Raydist chart was constructed on the scale of 1 : 80 000, using the Universal Transverse Mercator system of plane coordinates.

The siting of the stations, due to the character of the coast, did not enable determination of the wavelength with the system itself, since it was impossible to cross any of the base line extensions, and computations were based on a precise knowledge of the frequency and velocity of propagation of electromagnetic waves obtained from Norton's Tables.

By computing the wavelength in this manner, and since one half wavelength, as stated previously, represents the value of a hyperbolic lane at the base line, we obtained the number of hyperbolic lanes existing on each of the base lines, i.e. from Varela to Pelindà and from Pelinadà to Caravela.

The master station was installed on board the Survey Ship *Mondovi,* which carried out the majority of sounding operations.

When conditions at sea permitted, sounding operations were carried out by both the ship and a large gasoline motor launch.

The ship navigated according to indications supplied by the Raydist equipment, and the launch followed along a grid-line parallel to the ship's line, maintaining a constant distance and bearing.

The bearing from the ship was obtained by lining up two flags placed on the ship's bridge, and the distance by sextant measurements of the vertical angle of the ship's mast.

Times of sounding were determined by signals from the ship, which also directed the course changes.

As only the ship could take soundings with the Bagre instrument, bottom samples were obtained on alternate lines.

The soundings for Chart No. 214 were completed by mid-February, the Raydist operations having therefore taken slightly over a month.