ON THE PROPERTIES AND APPLICATION OF MODERN SHIPBORNE DIRECTION FINDERS

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There is no doubt that in consequence of their attractive performance, systems of hyperbolic and radar navigation have come to stay. It should not be assumed, however, in spite of the many papers recently published about these systems that all requirements of navigation can be met by employing them. That would be a fatal deduction. It may then be asked : in what is it that hyperbolic and radar navigation principally fail ? *Both systems fail in cases of distress in mid-ocean.* Hyperbolic systems are insufficiently accurate for this purpose in the middle, say, of the Atlantic, many hundreds of miles from the chain of shore transmitters. While what use is a radar set, with a maximum ship to ship range perhaps of 10 miles in similar circumstances ?

This example no doubt indicates quite clearly that in the future we cannot abandon the use of a radio aid to navigation, which has proved itself in the past, i. e. a sufficiently powerful *transmitter* in the D./F. wave band *on board ship* and a *radio direction finder.* This is important especially with regard to the great value of a shipborne direction finder in cases of air disasters, as often the success of rescue efforts entirely depends on a proper homing to the place of distress. Consequently, in the following paper an investigation will be made of the means whereby the properties of shipborne W./T. transmitters and direction finders may be improved.

Ships' W./T. *transmitters,* with an aerial circuit performance of 200 watts have reached a limit, which should seldom be exceeded having regard to an economical design of the electric supply of ships of smaller size. The transmitter then continuously takes up approximately 1 kilowatt output from the ship's supply. As the power radiated from the antenna on account of the low radiation resistance of the aerial is constant within the order of a few watts in the medium wave band most suitable for direction finding (600 to 1,000 m.), there must exist a fixed optimum aerial alignment at least for some main waves, which can be determined by checking the aerial circuit. If this requirement is realized by proper design of the circuit, then the limit is reached of what is technically possible. It may then with some certainty be expected, that the bearing of a ship making an S. O. S. may be determined with reasonable accuracy from a distance of 150 miles by an observer using a rotating frame aerial. Frequently the site of the transmitting aerial, especially in small vessels, is chosen so badly that a satisfactory electrical neutralization from adjacent structures and metallic parts of the ship is not practicable. The result is then that only a fraction of the radiation power producible under favourable aerial conditions, may be available for radiation. In such cases the attainable transmission ranges may be considerably reduced. Any shipmaster therefore, knowing his responsibility for safety of life at sea, will pay special attention to the question of the best possible rigging of his aerial and lead from the transmitter.

In comparison with the technical possibilities of modern *radio direction finders,* a striking disproportion may be observed in the design of sets in use on board most ships. An improvement of the method introduced by Bellini and Tosi in 1908 began about 1930, which led rapidly to the production of goniometer bearing systems of high sensitivity. Nevertheless, on board most merchant ships, all that are still to be found are the old-fashioned rotating frame aerials. Mariners cannot be held responsible for this. It is understandable that an experienced shipmaster will not readily give up approved methods and instruments which he has been using satisfactorily for a long time. Nor can he be expected to make such a study of modern technical developments, that he can make proposals for the equipment of ships with new nautical instruments. Shipping should demand, rather, that newly developed instruments, which lead to a considerable improvement in nautical methods, be demonstrated in a convincing operational test. This often is not at all easy, especially when quite understandable prejudices against innovations have first to be removed. But in the same way as no shipmaster would any longer dream of using a sounding tube in preference to an echo sounder for his determination of depth, so there should be a demand for the general employment of a *modern goniometer direction finder* for reasons of improved navigation and enhanced safety of ships at sea, instead of the far too insensitive rotating frame aerial. The firm Kieler Hochseefischerei AG., who are especially interested in improving their shipborne direction finders, have shown great initiative, and they have fitted goniometer direction finding systems with large plane cross coil aerials of high output in three of their newly-built fishing vessels.

As in general little is known in shipping circles about these instruments, we will now give somewhat close consideration to the physical foundations of the system. Then its advantages compared with a rotating frame will be explained, and in conclusion, a description of the installation of a goniometer direction finder in the Survey and Research Vessel *Gauss* of the German Hydrographic Institute will be given.

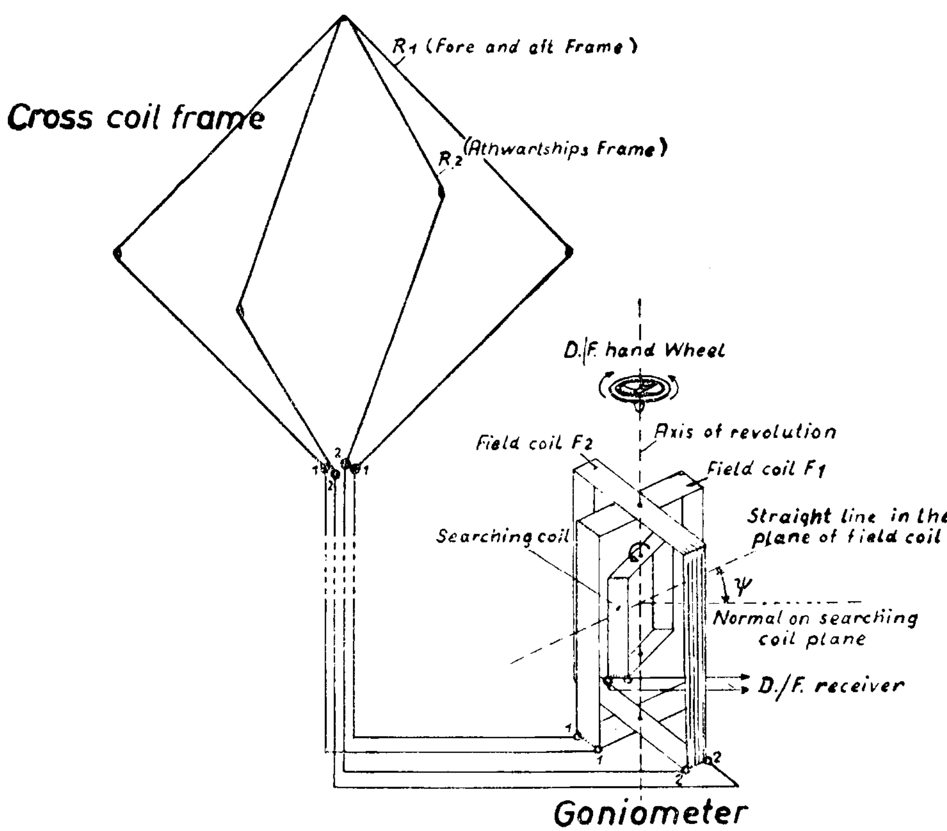


FIG. 1

The goniometer direction finder (fig. 1) uses, instead of a rotating frame, an aerial system of two frames, which are fixed at right angles to each other. As with a rotating frame instrument, the bearings are taken by ascertaining a minimum intensity of sound not in the direct field of the incoming wave, but in an exactly similar auxiliary field. The *cross coil aerial* receives the impulses from the observed transmitter and feeds them to the field coils of a goniometer. The bearing is made with a searching coil linked electro-magnetically to the field coils, and rotatable by an outer wheel turned by hand. This searching coil now performs the familiar duties of the rotating frame and supplies the directive electric voltage for the receiver. The principle of the system may best be understood from a study of the polar diagram of the cross frame aerial shown in fig. 2. This is a two wire circuit diagram formed by the characteristic curves of two frame coils mounted at 90° to each other. The plane of frame 1 may be taken as the reference line. A wave arriving at an angle φ in frame 1 induces a voltage of the order Um. cos φ, and in frame 2 of Um. sin φ. The field of the incoming wave that is thus analysed into two components at right angles to each other is then reconstituted by the field coils F_I and F_2 (fig. 1) of the goniometer. If ψ be the angle between the normal of the searching coil and the plane of field coil F_I (i.e. the normal of field coil F_2), then the highest voltage is induced in the searching coil, when the plane of the searching coil coincides with the plane of the inducing field coil and thus (considering the effect of F_I) the angle ψ becomes 90°. The voltage induced by the auxiliary field in the searching coil therefore is proportional to sin ψ regarding the effect of F_I, and proportional to cos ψ regarding the effect of F_2. Thus we obtain for the voltage induced in the searching coil

$$U \text{ induced} = U_I . (\cos \varphi . \sin \psi) + U_2 . (\sin \varphi . \cos \psi).$$

If the two frames are the same in size and characteristics $U_I = U_2$. Substituting U for U_I and U_2.

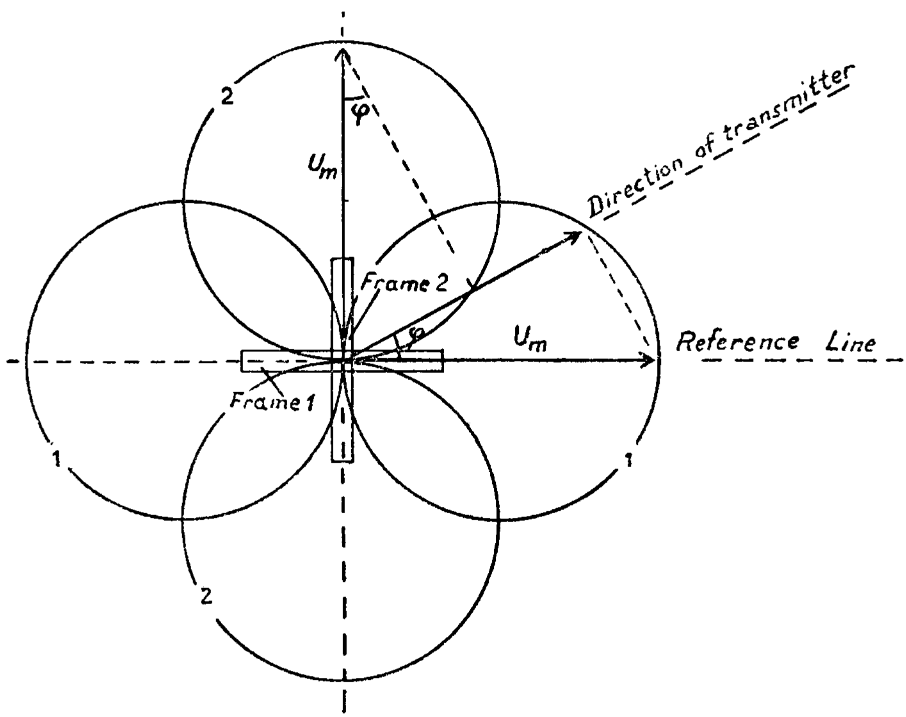


Fig 2 Directional Characteristic of a Cross Coil Frame.

$$U \text{ ind} = U. (\sin \psi . \cos \varphi + \cos \psi . \sin \varphi) = U. \sin (\psi + \varphi).$$

This indicates that the same analytical law as for the rotating frame is true for each angle of incidence φ of the bearing waves as the searching coil is turned from $\psi = 0° - 360°$. Hence, the *characteristic of the goniometer direction finder* is seen to be that of a *two wire circuit diagram*. The minima of sound intensity occur when the angular position of the searching coil is such that $\psi = - \varphi$ and $\psi = 180° - \varphi$ respectively.

The minimum signal with a goniometer cross coil aerial is blurred as a result of high aerial effect in the same way as it is with a rotating frame aerial. The reradiation field of

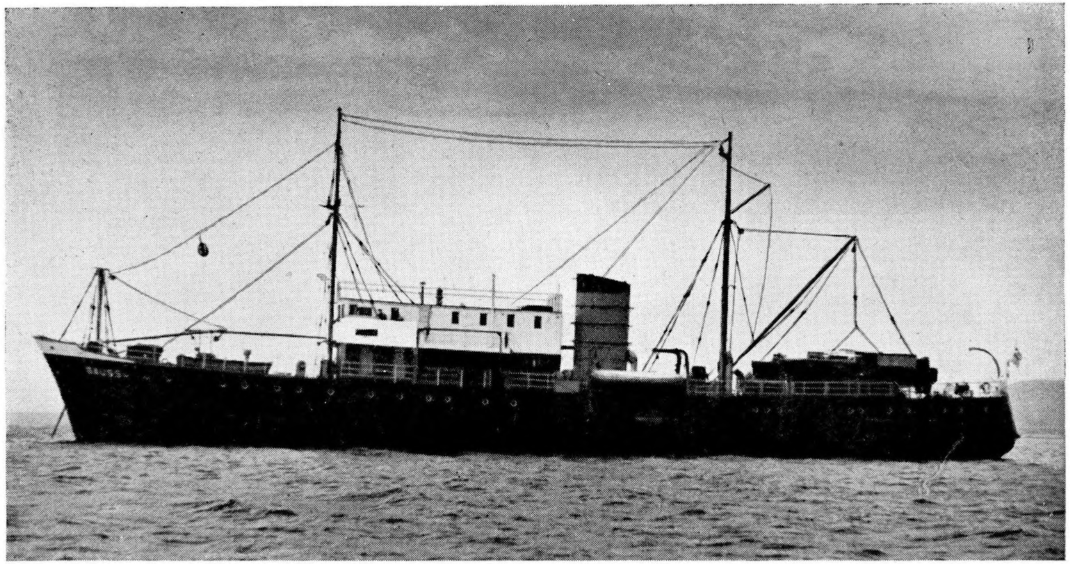


FIG. 3

Survey and Research Vessel "Gauss"
of the German Hydrographic Institute, Hamburg.

the ship, as known, also causes an additional blurring depending on the bearing of the incoming signal. The *correction* is made by an auxiliary aerial voltage suitable controlled with regard to amplitude and phase; *sense finding* is done with the cardioid diagram by algebraic addition of the cross coil aerial and (equal) auxiliary aerial voltage.

What are the advantages of a goniometer direction finder over a rotating frame direction finder ? We will consider first the *installation*. It is known that frequently difficulties arise when installing a rotating frame set. The hand wheel must usually be operated in the chart room, and the rotating frame which is mechanically connected to the hand wheel ought to be mounted on deck in a position clear of electrical interference. If a position cannot be found conveniently near, mechanical and electrical difficulties in transmission will prejudice good results. *With the goniometer direction finder these disadvantages cannot arise.* As rotating parts have been avoided in the receiving frame, the local separation of cross coil aerial and goniometer is of no significance, and it is possible to choose a site for the cross coil earial *which is technically the most suitable.* If low capacity high frequency cables are used, a cable length of up to 80 metres between the goniometer and cross coil aerial is quite permissible.

Much greater efficiency in taking bearings results from the greater cross coil aerial plane of the goniometer direction finder. If a sensitivity of 1° minimum width for audible reception be a measure for the efficiency of the instrument, then with a common rotating frame aerial of approximately 0,5 square meter an intensity of field of approximately 100 to 150 microvolts/meter is necessary to induce a voltage of approximately 10^5 volts in the frame. As it is possible to install goniometer cross coil aerials of a plane up to 75 square meters in ships, the sensitiveness of bearing of 1° minimum width may be increased *fifteen to thirty times.* The input of intensity of field then decreases to 5 to 10 microvolts/meter. What this important increase in efficiency means in service may clearly be shown by the following consideration : assume that in a ship at a great distance from the observed transmitter there is a receiving field intensity of only 5 microvolts/meter, then with a normal rotating frame aerial the same sensitivity and the same reception range could be reached only if the transmitter output were increased as much as a thousandfold. It is evident that for technical reasons as well as for reasons of economy there is a limit to such measures.

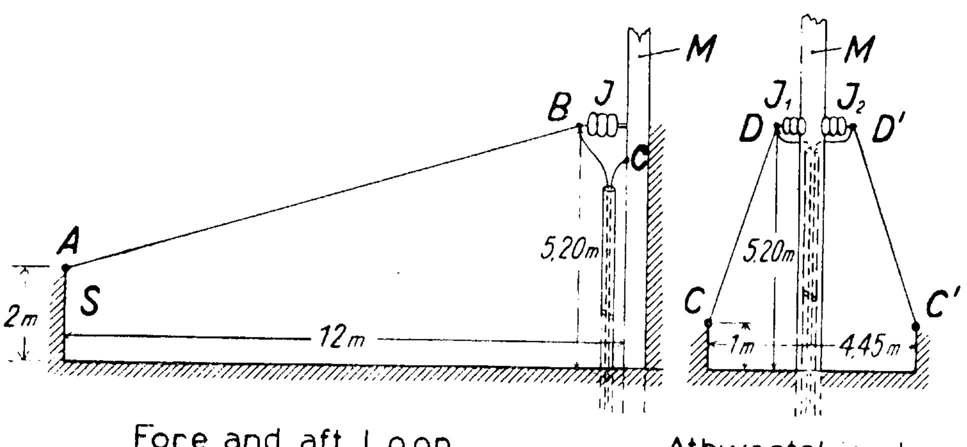
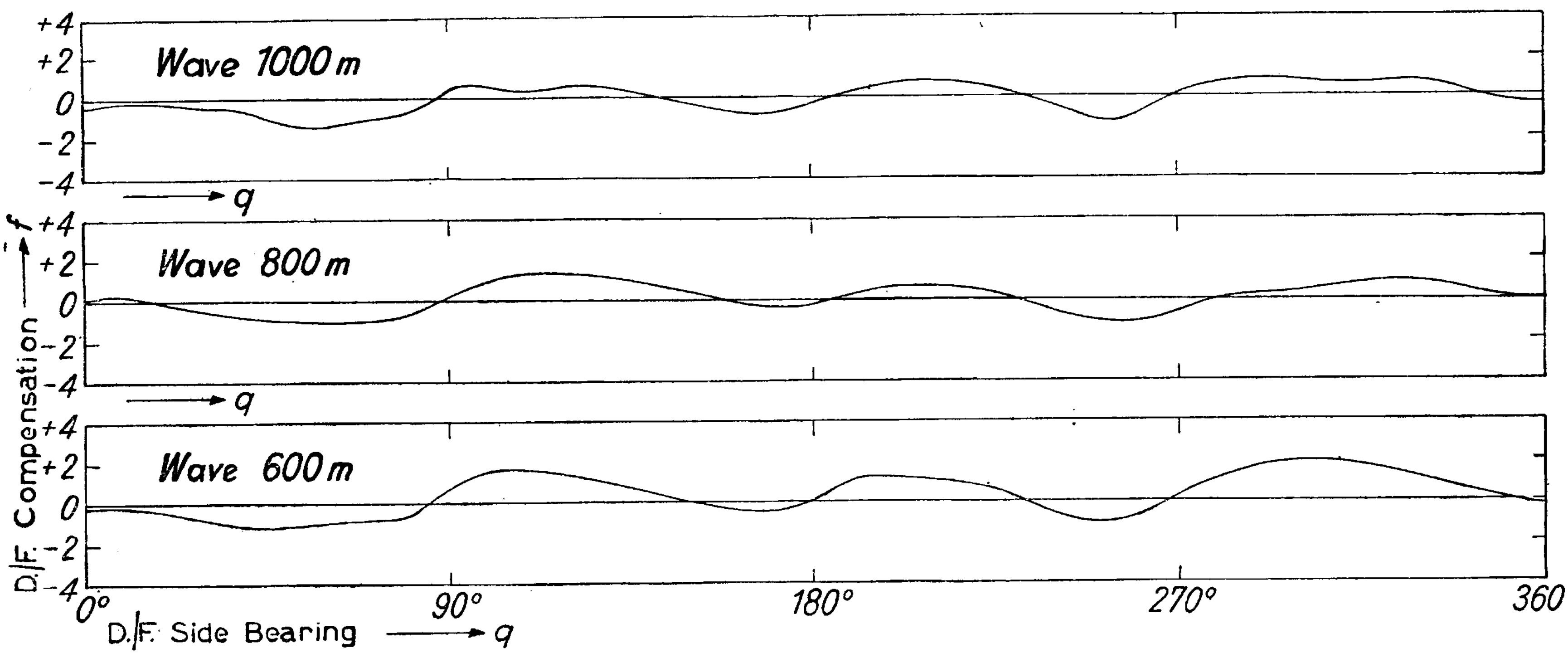


Fig. 4

Another advantage of the goniometer direction finder is the convenient and rapid *sense finding*, as there is no necessity to turn the whole mass of the rotating frame, since only the small searching coil is moved. By special arrangements in the circuit it is even possible to dispense with the mechanical rotation of the searching coil, by making an electrical 90° turn in the goniometer field.

Lastly the *compensation* is done by *simple switching arrangements in the goniometer* instead of by bulky compensators in the direct field as with rotating frame instruments.

In fig. 3 and 4 may be seen how the installation of the goniometer direction finder



Wave 1000 m
Wave 800 m
Wave 600 m
+4
+2
0
-2
-4
D.F. Compensation → f
0°
90°
180°
270°
360°
D.F. Side Bearing → q

Fig. 5

cross coil aerial was arranged in the German Hydrographic Institute's Survey and Research Vessel *Gauss.* Fig. 3 shows a view of the ship with the compass platform between foremast and funnel. In fig. 4 details of the arrangement of the cross coil aerial and the loop system above the compass platform are shown. Fig. 1 schematically suggests that the loops are rigged with their lower ends connected to the goniometer cables. The cable connections in *Gauss,* however, are made at the top of the cross coil aerial. As a result, it is not necessary for the loops of the frame between the terminal points to consist of closed wire loops, the installation of which aboard ship is often rather difficult. *Merely a few wires connected to certain conductive points of the ships hull or upper works are sufficient.* The required frame surfaces then are formed by these wires, which are closed into loops by the electrically conductive parts of the ship. The efficiency of the system is influenced not only by the visible plane between wire connections and ship's structure, but also by the considerably extended plane of the vertical metallic parts of the ship in the vicinity of the frame.

The *fore and aft loop* arranged midships (fig. 4) is formed by a wire connection AB between a rail stanchion S of one metre height abaft the compass platform (rail also 1 metre high) and an insulator J on the foremast M and completed by the ship's structure and mast (both shown hatched). The goniometer leads are connected, one to the insulated upper end B of aerial AB, the other to an earthed connection C at the mast. The visible plane of the fore and aft frame measures 43,2 square metres.

The *athwartships loop* consists of two wire connections CD and C'D', which at C and C' are electrically connected to the port and starboard rails with their upper ends at two insulators J_1 and J_2 at the mast M, and is completed by the ship's structure (hatched). The connection of the athwartships loop to the second goniometer field coil is made by connecting one goniometer lead to the wire connection at D and the second lead to the second wire connection at D'. The visible plane of the athwartships frame is 14,3 square metres.

Comparing the visible planes of the fore and aft, and athwartships loops, there is a ratio of 3 : 1 arising from the necessity of keeping the loops *clear of the compass platform and upper deck.* This is no disadvantage in the goniometer system, since asymmetrical sizes of the loops are electrically balanced by controlling devices in the goniometer circuit. The effect of the ship on all D./F. sets is to act like an inductive detuned fore and aft loop, and thus even with fore and aft, and athwartships loops of equal planes there is a quadrantal deviation to be corrected, allowance for which is made by the same controlling devices in the goniometer circuit. Since there is no technical objection to loops of dissimilar size, they may be arranged to suit practical considerations of rigging.

On the *Gauss,* with no D./F. compensation operating, there was an initial quadrantal deviation of approximately 28° (with a wave length of 800 metres), caused, as explained above, by the radiation from the ship, and the unequal loops.

Fig. 5 shows the low residual values after correction for wave lengths of 1,000 m. 800 m. and 600 metres. The quadrantal component is almost entirely removed.

The above discussions about the properties and application of an efficient shipborne direction finder clearly prove the necessity for the general adoption of such an instrument, and suggest the lines of further progress in the same direction. This refers especially to the development of *methods that will give bearings free from night error and twilight error* as well as of instruments *for visual presentation of the bearings.* In these directions promising possibilities are believed already to exist.