# SUBJECTIVE AURAL RESULT OR OBJECTIVE VISUAL INDICATION OF RADIO DIRECTION FINDING ?

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Some time ago, in a paper entitled : « On the Properties and Application of Modern Shipborne Direction Finders », a striking disproportion between the state of physical development and technical possibilities of shipborne Radio Direction Finders, was discussed here (1). Meanwhile in some hundreds of ships of German and foreign nationality the rotating frame direction finders with their relatively low sensitivity have been replaced by modern goniometer direction finders. Their essentially higher efficiency was gained either by larger freely-rigged cross coil aerials in connection with air-goniometers (firm of C. Plath, Hamburg) or by self fixed keeping cross coil aerials, only slightly larger than rotating frames, in connection with iron goniometers (Telegon Direction Finder of Telefunken, Berlin). However, with regard to all freely rigged aerials it is of particular importance that these need not consist of closed wire loops, the installation of these in the desired size being in most cases very difficult on board ship. In consequence, the cross coil aerial frames so formed consist of single-wire connections and parts of the ship's hull or upper works. In this manner mounting of frames of about 6 to 60 square metres of plane, according to space conditions, is easily possible on board ships.

The high sensitivity of the goniometer equipments mentioned, effected that, compared with bearings taken with a rotating frame, the reliable bearing distance between radio beacons (light-ships) and ships receiving the bearing signals could be increased about sixfold (2). Therewith the sensitivity of goniometer direction finders has reached an upper limit, which technically cannot be exceeded (3). In practice, however, this is of no consequence as a further increase of sensitivity of direction finders is not required.

The bearing devices considered, however, have an inherent, basic lack. The bearings are taken, as is well known, in a subjective manner by aural observation of the minimum signal strength of the incoming wave, as

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(1) H. GABLER : *On the Properties and Application of Modern Shipborne Direction Finders :* Inter. Hydrogr. Review, vol. XXVII, N° 2, Monaco, November 1950.

(2) H. GABLER, G. GRESKY and W. RUNGE : *Comparative Researches between* with 43 illustrations, published by the German Hydrographic Institute, Hamburg, 1951, pag. 50 pp.

(3) H. GABLER : G. GRESKY and W. RUNGE : *Comparative Researches between Frames and Loops for Shipborne Direction Finders :* Telefunken-Zeitung, 25, n° 94, 1952, Berlin.

in the vicinity of minimum the differences in the signal strength are the highest, and, therefore, the searching coil of the goniometer can be turned into this position with the greatest degree of accuracy. The voltage induced in a frame is of the value :

$$U_R = E \cdot 2\pi . w. \frac{F}{\lambda} . \cos \varphi \ (1)$$

where E is the electric intensity of field at the bearing device, F the plane of frame, w the number of windings on the frame, $\lambda$ the wave-length and $\varphi$ the angle which is enclosed by the plane of frame with its direction to the incoming wave. For the minimum positions $\varphi_1 = 90°$ and $\varphi_2 = 270°$ the induced frame voltage $U_R$ becomes zero, provided that a non-directional aerial effect, arisen from an asymmetric frame, has been entirely compensated by an equally large auxiliary aerial voltage of reverse phase. Yet even after accomplishment of this important supposition it often may be difficult, in contrast to radio bearings on land, to receive useful radio bearings aboard ships from the subjective aural result. This proves true especially at small receiving field strengths, where the ratio of effective level to disturbance level of the received voltage becomes exceptionally unfavourable (4) and when the ship is moving in a heavy sea whereby the observer may be irritated by continual, sometimes considerable displacements of the minimum to both sides. Then great experience in bearing technique is required in order to get some reliable bearings at all means. Bearing conditions become particularly difficult in twilight or at night, when abnormal conditions of wave-polarisation occur, and the electric vector E has thereby been turned out of the vertical plane placed in the direction of propagation. This leads to a « wandering » of the bearing minimum at a simultaneous oblique incidence of the wave from above, the consequence of which is a bearing error. For an angle of polarisation $\psi$ measured against the vertical and an angle of elevation $\vartheta$ of the incoming wave, the voltage induced in the frame becomes :

$$U_R = E \cdot 2\pi \frac{F}{\lambda} . (\cos . \varphi \cos \psi + \sin \varphi \sin \psi \sin \vartheta) \ (2)$$

For $\psi = \vartheta = 0$ the double circuit diagram results in accordance with equation (1) that is, as will be seen, the normal case. Equation (2), however, which shows the general directional characteristic of a bearing frame, supplies the value of directional errors produced for any one angle of polarisation $\psi$ and for any one angle of elevation $\vartheta$.

Furthermore, rotating fields (elliptic polarisation of wave) may arise from phase differences by the summing up of one surface wave and one sky wave or by summing up of two sky waves at the place of the direction finder. Both produce a dimness of minima. As a result of these effects the bearing fluctuates with entire irregularity. The minimum in rapid succession appears once clear, once dim; the auxiliary aerial supply cannot be regulated being also subject to continual strong changes. In such cases, therefore, it is practically impossible to receive reliable bearings by aural results.

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(4) H. GABLER : *On the Quality of the Minimum at Radio Direction Finding.* Deutsche Hydrogr. Zeitschrift 4, 175-181, 1951.

The above-mentioned difficulties arising in aural bearings may be recognised more rapidly and taken into consideration more easily, if the bearing minimum is no longer an aurally-determined value, but is ascertained by an objective visual indication (5) of the bearing. Applying this principle of Instantaneous Direct Reading radio direction finding which was first proposed by R. A. Watson Watt (6), fixed cross coil aerials are used — as the reader will know — which are so orientated when assembled aboard a ship that one aerial is in the fore-and-aft direction while the other is in the athwartship direction (illustration n° 1).

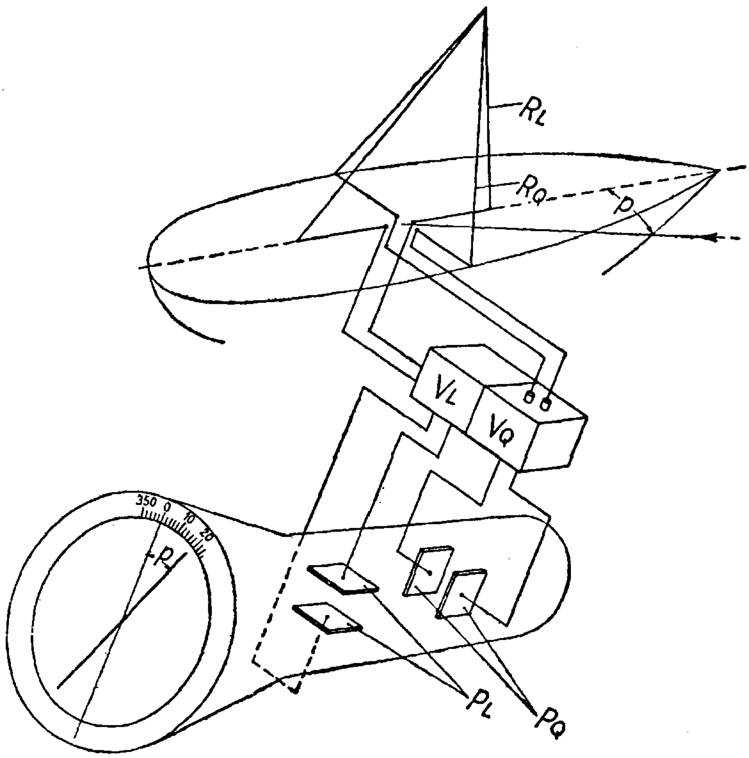


*Fig.* 1. — Diagrammetric view of a direct reading direction finder

The first instantaneous direct reading direction finder built for German and foreign ships is the type built by Messrs C. Plath, Hamburg (7) (illustr. n° 2). The voltages induced in the two aerials by the incident transmitting wave are passed to the two pairs of deflecting plates of the cathode-ray tube $P_L$ and $P_Q$ through two separate amplifying channels $V_L$ and $V_Q$ whereby the phases and amplitudes of the loop voltages should be maintained

(5) M. WACHTLER : *Bordfunkpeiler für fehlerfreie Dämmerungs- und Nachtpeilungen,* Deutsche Hydrogr. Zeitschrift 3, 353-362, 1950.

(6) R.A. WATSON WATT and J.F. HERD : *An Instantaneous Direct Reading Radiogoniometer,* Journ. I.E.E., 64, 579, 1926.

(7) W. KUNTZE : *Neuerungen und Verbesserungen der Funknavigation,* « *Hansa* », ZS für Schiffahrt, Schiffbau, Hafen, 89, 284-287, 1952.

in the same relation throughout. On the screen of the cathode ray tube, a path of the spot will appear which forms the same angle with the direction of reference as the incident wave forms with the fore-and-aft direction of the ship. The only requirement is that the 90° correcting values which are produced by the reflecting properties of the hull have been compensated by the well-known electrical compensation of the two aerials in the same way as with the cross coil aerials of the goniometer. The bearing is read from two concentric scales, either against the fore-and-aft direction of the ship or directly against the meridian of the ship's position. The reading can be carried out conveniently by a revolving ruler having an engraved bearing file.

The bearing receiver has a frequency range of 240 to 535 kcs. The frequency desired can be adjusted at a frequency scale below the screen.

In order to control the aerials and the accurate working of the two amplifying channels, as far as the phases and amplitudes are concerned, the two aerials are connected in series by a calibrating switch and the summed-up voltages are passed to either of the two amplifying channels. The path of the spot then has to be adjusted exactly to 45° by regulating the amounts and phases of the amplifying channels accordingly at the frequency of the transmitter to be found. As a result of the aerial connection of the aerials, the aerials are at the same time subject to a control of their satisfactory passage.

Since the length of the path of the spot depends on the effective voltages at the pairs of the deflecting plates in the cathode ray tube, the sensitivity of a direct reading direction finder also depends on the size of the receiving aerials as in the case of any goniometer d.f. In order to obtain as great a bearing sensitivity as possible, very large freely rigged loops will, if possible, be used in this type as well. A great advantage was that the excellent experiments made with large loops during two decades, could be used in this connection. However, as the leading principle in direct reading goniometers is based on a maximum bearing, sufficiently accurate bearings may still be obtained if the path of the spot, owing to too low an intensity of the receiving field, does not cover the whole diameter of the screen, but is only a few millimetres in length.

Open reflecting aerials which, in the case of frame direction finders, result in an indefinite aural minimum, will in the case of direct reading direction finders produce a rotating field between the plates and the spot will trace out an ellipsis. The voltage producing an indefinite aural minimum aboard ship is semi-circular, passing at 0° and 180° via Zero. Accordingly, the path of the spot is maintained at these bearing angles, while the ellipse produced at other bearing angles is maximally extended, if the waves are incident under 90° and 270°. Analogous to the removal of disturbances in aural direction finders by making the minimum clearer with the aid of an auxiliary aerial, the tracing out of the path of the spot to an ellipsis in direct reading goniometers could be avoided by adequate wiring. Such an action is, however, unnecessary since, in the case of flat ellipses, satisfactory bearings can be obtained by bringing the bearing ruler in line with the large axis of the ellipsis.

The indication in the direct reading direction finder is as ambiguous as the indication in aural direction finders. In order to determine the sense,

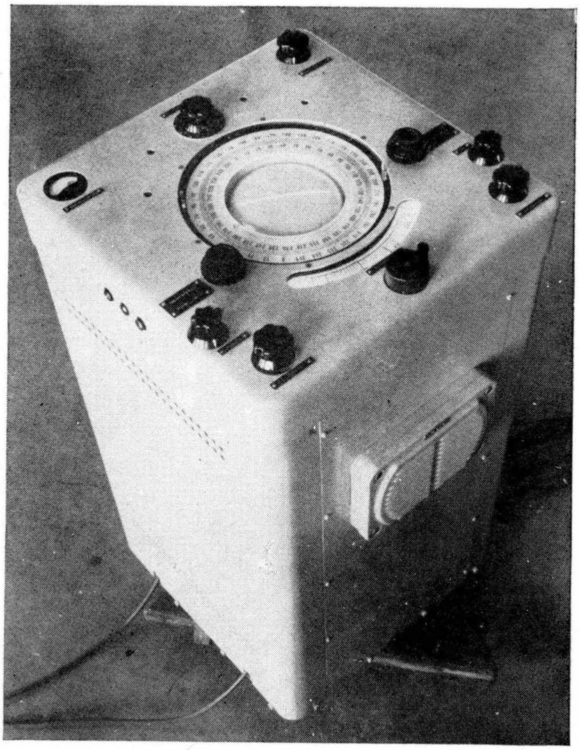

*Fig.* 2. — Direct reading direction finding equipment of Messrs C. PLATH, Hamburg

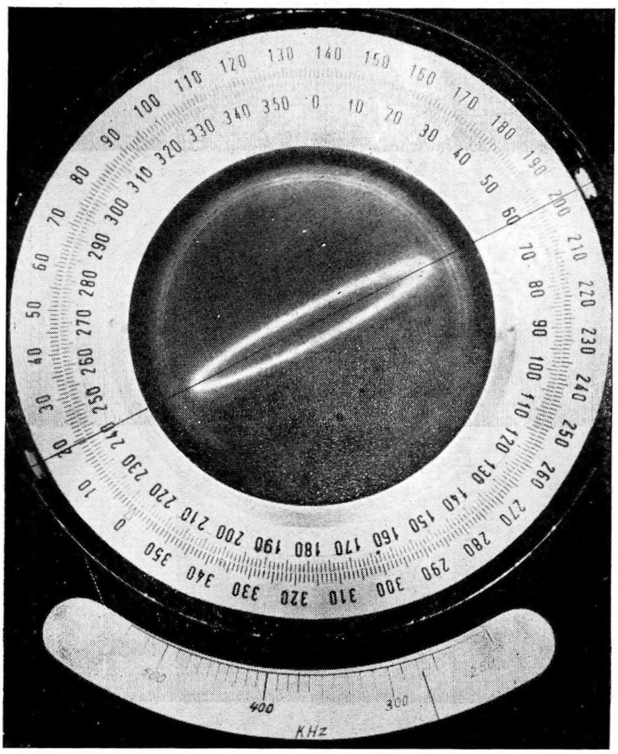


*Fig.* 3. — Bearing indication with re-radiation field

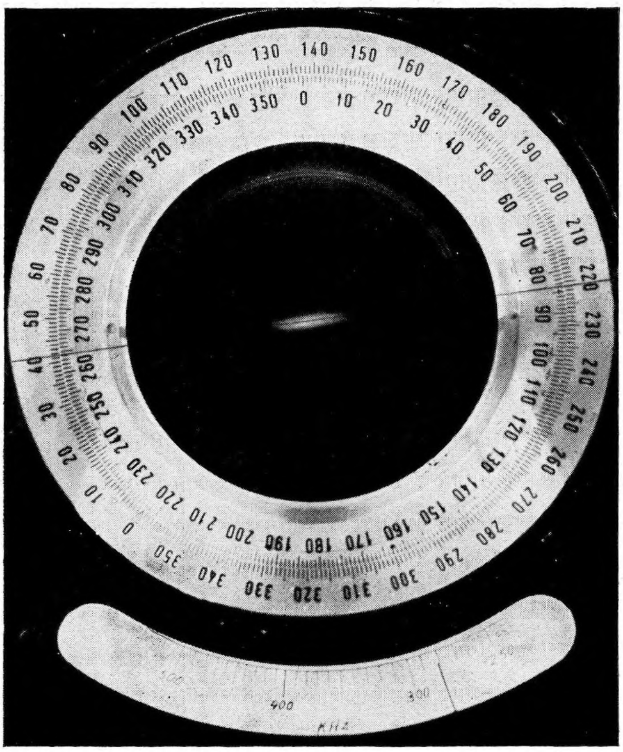


*Fig.* 4. — Bearing indication of transmitter having an extremely low field intensity

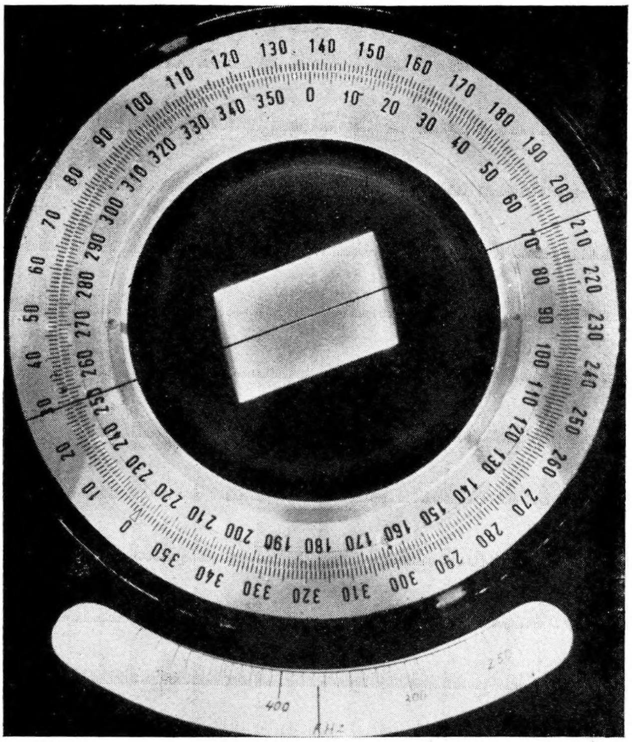

*Fig.* 5. — Bearing indication with a disturbing transmitter it is in either case necessary to use an auxiliary aerial. The sense may then, e.g. be determined by conveying the voltage of the auxiliary aerial to the surrounding cylinder of the cathode ray tube through a third amplifying channel which has to meet the same requirements as the amplifying channels $V_L$ and $V_Q$. This extinguishes one half of the spot or the ellipsis respectively, and makes the bearing unambiguous. However, it is not at all desirable to obtain such an automatic, unambiguous indication. The reason is that, in order to get accurate bearings even with small intensities of the receiving field, it is preferable to make use of the advantages of a longer path of the spot as obtained by the ambiguous indication, and also of the possibility of getting a more accurate adjustment to the large axis of the ellipsis. In this case, the sense can be determined by inserting a cardioidic switch by means of a switch for the determination of the sense as in aural direction-finders. This saves at the same time the amplifying channel required for automatic direct reading.

The indication of a bearing will only appear as a straight line, if only the bottom wave of a transmitter becomes effective and no open reflecting aerial exists. If the bottom and the sky waves, or two sky waves respectively, incide at the receiving position at the same time the path of the spot is also split into an ellipsis. In this case the ellipsis is liable to fluctuate by larger or smaller angles. If the fluctuations are by a somewhat regular mean angle, comparatively satisfactory bearings may still be obtained by adjusting the bearing ruler to this mean bearing angle.At any rate it is always possible to judge the quality of the bearing by the fluctuations and the width of the ellipsis, and to estimate without any difficulty whether or not a bearing is still satisfactory.

Illustrations 3 shows the adjustment of a transmitter on the screen of the direct reading direction finder which is incident with a comparatively great intensity of the field. The luminous dash is split to form an ellipsis by open reflecting aerials aboard. But even if the luminous dash is short owing to the low intensity of the receiving field, a bearing accurate to about $\pm$ 1° may be obtained, as show in illustr. 4, by adequaly adjusting the bearing ruler. In this case, the width of the minimum in aural bearings would amount to about 40° (!), which corresponds to an intensity of the receiving field of only about 1 μV/m. Aural bearings being praticable only with the width of the minimum being <10°, this example is a direct demonstration of the great superiority of the bearings by maximum in direct reading direction finders.

Another great advantage of the direct reading system is that satisfactory results may still be obtained, even if a disturbing transmitter interferes, in which case no aural bearings are possible. The indication is then extended to form a parallelogram (illustr. n° 5), the sides of which indicate the directions towards the two transmitters. The true transmitter can then be recognised from the code of the radio beacon to be found, since during the transmitting intervals only the direction of the disturbing transmitter is shown and *vice versa*. Moreover, the W/T signals of the transmitter may be listened-in-to simultaneously. This is particularly important for distress signals, and enables plain language messages to be received in addition to the continual bearings.

Finally, an additional remote indication by repeaters may be provided. Thus ships are now able to receive a continuous indication of a bearing also, for instance, on the bridge, to reach a radio transmitter of a ship in distress.

Accordingly, an objective cathode ray indication of bearings has the following advantages as compared with the determination of the direction of transmitters by finding the bearing minimum by the aural method :

1. An automatic and, therefore, instantaneous direct reading indication after adjustment to the frequency of the transmitter from which the bearing is taken.

2. Independence of a training in bearing technique and of the experience of the observer.

3. A possibility to take bearings at extremely low intensities of the receiving field, since the maximum bearing is used.

4. Effective elimination of interfering transmitters, since the direction is indicated simultaneously towards both transmitters.

5. Simultaneous observation of W/T signals of the transmitter, from which the bearing is taken.

6. The possibility of judging any single bearing at once with regard to its reliability (bearing quality) and thus eliminating bearings of uncertain character. This is particularly important in cases of twilight and night effects.

7. Additional remote indication of bearings by repeaters. If all these advantages are critically examined, there can be no doubt that by the construction of a bearing device with objective visual indication, a decisive step has been made in the field of direction finding. We believe that a considerable increase in the safety of shipping will be gained by the use of direct reading cathode ray direction finders and that the aural bearings - exclusively in use for the last 40 years - will in future be replaced by direction finding with objective visual indication.