July 28, 1964 J. F. HATCH 3,142,838

RADIO GONIOMETERS AND RADIO DIRECTION FINDERS INCORPORATING THE SAME

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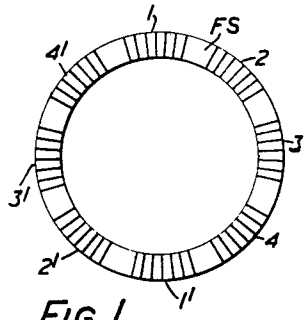

FIG. 1.

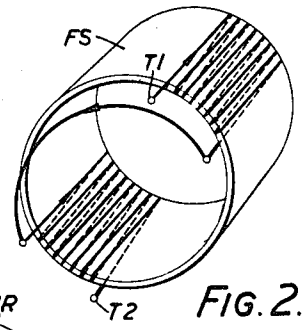

FIG. 2.

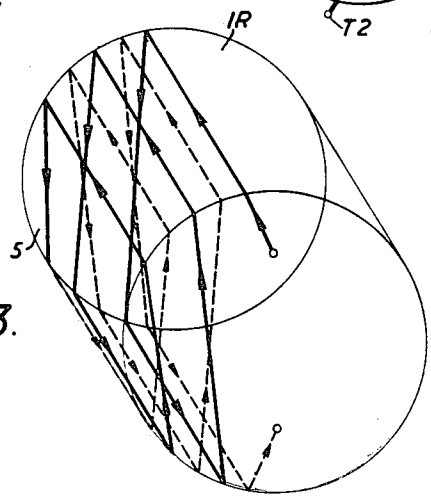

FIG. 3.

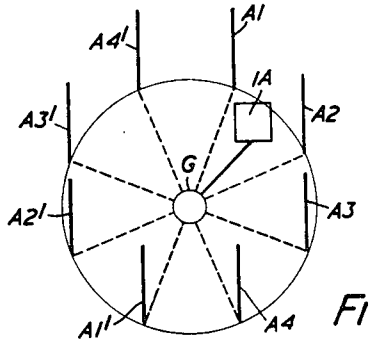

FIG. 4.

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6 Claims. (Cl. 343—124)

This invention relates to radio goniometers and radio direction finders incorporating the same and more particularly, although not exclusively, to such goniometers and direction finders intended for operation in the high frequency (H.F.) waveband extending between the approximate limits of 2 mc./s. and 30 mc./s.

In a conventional direction finder operating in the H.F. band there are four receiving aerials, symmetrically disposed on a circle having a diameter of approximately 0.4λ where λ is the wavelength at the highest frequency which the direction finder is designed to receive, and connected to the two mutually perpendicular stator coils of a goniometer having a pick-up coil on its rotor, diametrically opposed aerials being connected to the opposite ends of a stator coil. For operation of the direction finder over a frequency range of 2 mc./s.–20 mc./s. two goniometers are used, one for the upper part of the frequency band and one for the lower, in order to provide acceptable sensitivity and acceptably low errors. It is well known, of course, that sensitivity may be improved by increasing the spacing of the aerials and that increase in spacing errors and ambiguities in the ascertained direction of a received signal resulting from such increase in spacing may be avoided by increasing the number of aerials. This, however, leads to the requirement of a goniometer having more than two stator coils—a requirement which has been regarded as very difficult to satisfy due both to the danger of undesirable coupling between stator coils which are not perpendicular to one another and the difficulty, in a goniometer which is physically sufficiently small to operate satisfactorily at the highest frequency in question, of providing adequate efficiency of signal transfer between the stator and rotor coils.

It is the object of this invention to provide improved radio goniometers which shall effectively satisfy the above requirement and it is a further object to provide improved radio direction finders which shall be of increased sensitivity as compared with comparable known direction finders.

According to this invention, a radio goniometer comprises two co-axial relatively rotatable members, one within the other, the outer member being formed of a ring-like ferrite body with at least two windings equally spaced around the ring, the inner member being provided with a winding for magnetically coupling in turn, during rotation, with each of said windings on the outer member, said winding on the inner member being wound so as to progress initially in one direction and subsequently in the opposite direction so that all the turns thereof are effectively in parallel planes.

The expression "ring like body" is used in a wide sense to include any body which circularly surrounds its straight axis. The section of the body may be itself circular, i.e. the ring may be toroidal, but more generally the section will be of strip-like form, the body being cylindrical.

Preferably at least the inner member is provided with a winding which progresses initially in one direction and subsequently in the opposite direction so that all the turns thereof are effectively in parallel planes. More preferably, however, both the inner and outer members are provided with such windings.

Preferably in the case of the inner member there are two such windings connected in parallel, one on each side of the centre line.

In a preferred construction the outer member is a stator of cylindrical form and is provided with four windings.

According to a feature of the invention, a radio direction finder incorporating a goniometer as above described comprises said goniometer, a plurality, equal to twice the number of windings on the goniometer outer member, of linear aerials equally spaced around a circle, means for connecting each pair of diametrically opposite aerials to the opposite ends of a corresponding winding on the outer member of said goniometer, and means for utilising signals derived from the winding on the inner member of the goniometer for ascertaining the direction of arrival of received radio waves.

The invention is further described with reference to the accompanying drawings in which FIGURES 1 and 2 are diagrammatic representations of the stator, and FIGURE 3 a diagrammatic representation of the rotor, of a radio goniometer in accordance with this invention. FIGURE 4 shows diagrammatically a direction finder incorporating the goniometer of FIGURES 1, 2 and 3.

Referring to FIGURE 1, the goniometer stator comprises a ring-like ferrite body FS of cylindrical form carrying four windings wound around its section. Each winding is comprised of two half windings and there are therefore, as illustrated, eight similar hald windings symmetrically disposed on the ferrite cylinder. Each winding is made up of two diametrically opposed half windings whereby one winding is constituted by half windings **1** and **1'**, another by the half windings **2** and **2'**, a third by half windings **3** and **3'**, and a fourth by half windings **4** and **4'**. The spacing of the turns of each winding and the spacing between adjacent windings are preferably arranged to be equal, as shown, so that adjacent turns, whether on the same winding or on different windings, are equally spaced from one another. In the illustrated example each half winding is comprised of eight turns each embracing 5° of arc.

The interconnections between the half windings on the stator are represented in FIGURE 2 in which, for simplicity, only two half windings, together constituting a single stator winding, are shown. It will be seen from FIGURE 2 that the two half windings illustrated are similar windings and that they are interconnected in such manner that the magnetic fluxes in the ferrite cylinder FS, resulting from the application of a potential between the winding terminals **T1** and **T2**, oppose one another whereby a concentrated magnetic field extends diametrically across the cylinder FS.

Conveniently the windings may be so arranged that connections may be made to two of them, for example windings **1–1'** and **3–3'**, at one end of the cylinder FS and connections made to the other two, for example **2–2'** and **4–4'**, at the other end.

The goniometer rotor illustrated in FIGURE 3 comprises a hollow cylinder IR of insulating material carrying thereon two similar windings of which, for simplicity in drawing, only one, the winding **5**, is shown. It will be appreciated however that in addition to the illustrated winding which is wound on the left-hand side of the rotor as shown in the drawing, there is another similar winding covering the right-hand side of the rotor, the two windings being connected in parallel. As will be seen from the drawing, the turns of winding **5** lie approximately parallel to one another and progress towards the left, in the illustration, for 2½ turns and in the opposite direction for the remaining 2½ turns. As a result those parts of the winding **5** which have a component in

the direction of progression cancel one another out so that all the turns of the winding lie effectively parallel to one another.

The goniometer rotor is of course provided with central spindles mounted in bearings and when completely assembled the rotor is coaxially within the stator with the rotor winding coupling in turn, during rotation, with the different stator windings. Output signals from the rotor winding may conveniently be taken off from the rotor by means of slip-rings.

FIGURE 4 represents a direction finder in accordance with the present invention, incorporating a radio goniometer above described for operation over a continuous frequency band of 2 mc./s.–30 mc./s. Referring to FIGURE 4, there are eight linear vertical aerials A1, A2, A3, A4, A1', A2', A3' and A4' symmetrically disposed around a circle having a diameter of approximately $3/4\lambda$ at a frequency of 25 mc./s. The aerials are unbalanced unipole aerials and are mounted on the ground or on a simulated earth plane and have their bases insulated therefrom. It will be appreciated that diametrically opposite aerials, such for example as aerials A1 and A1', constitute together a directive aerial, the difference in the signals produced by the two aerials being indicative of the direction of arrival of an incoming radio wave. Accordingly each oppositely disposed pair of aerials is connected via coaxial cables to the opposite ends of a stator winding of goniometer G, which is a goniometer as illustrated in FIGURES 1, 2 and 3. Hence aerials A1 and A1' may be connected to half windings 1 and 1', aerials A2 and A2' connected to half windings 2 and 2' and so on. As will be apparent, the output derived from the rotor winding of the goniometer will vary in amplitude, as the rotor is turned, in dependence on the correspondence between the rotational position of the rotor and the direction of arrival of the incoming wave, and the output of the goniometer rotor is applied in the usual way to indicate apparatus 1A, as known per se.

In a practical case in which the spacing of diametrically opposed aerials was 9 metres and the height of each aerial was 6.1 metres, it was found that a direction finder using a single goniometer as above described had a sensitivity over the range 2–25 mc./s. of from 0.5 μv./m. and a negligible spacing error. A comparable known direction finder, on the other hand, having four symmetrically disposed aerials with a spacing of 6.1 metres and employing two goniometers, one for the lower part of the frequency band and one for the upper part provided, over a wave band of 2–20 mc./s., a sensitivity of from 1–6 μv./m. and exhibited a spacing error at 20 mc./s. of 5°.

I claim:

1. A radio goniometer comprising two coaxial relatively rotatable members, one within the other, the outer member comprising a ring-like ferrite body with at least two windings equally spaced around the ring, the inner member having a winding for magnetically coupling in turn, during rotation, with each of said windings on the outer member, said winding on the inner member being wound so as to progress initially in one direction and subsequently in the opposite direction so that all the turns thereof are effectively in parallel planes.

2. A radio goniometer as claimed in claim 1 wherein each winding on the outer member is wound around the section of said ferrite body and comprises two diametrically opposite half-windings arranged to produce opposing magnetic fluxes in said ferrite body.

3. A radio goniometer as claimed in claim 2 wherein each winding on the outer member is wound so as to progress initially in one direction and subsequently in the opposite direction so that each turn thereof is effectively in a plane perpendicular to the part of the ferrite body about which it is wound.

4. A radio goniometer as claimed in claim 1 wherein the inner member has two windings, one on each side of its center line, connected in parallel, each winding progressing initially in one direction and subsequently in the opposite direction so that all the turns thereof are effectively in parallel planes.

5. A radio goniometer as claimed in claim 1 wherein the outer member is a stator of cylindrical form and has four windings thereon.

6. A radio direction finder incorporating a radio goniometer as claimed in claim 1 and comprising said goniometer, a plurality, equal to twice the number of windings on the goniometer outer member, of linear aerials equally spaced around a circle, means for connecting each pair of diametrically opposite aerials to the opposite ends of a corresponding winding on the outer member of said goniometer, and means for utilising signals derived from the winding on the inner member of the goniometer for ascertaining the direction of arrival of received radio waves.

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