Aug. 1, 1961 A. TROOST ET AL 2,994,871

DUAL ADCOCK ANTENNA SYSTEM

Filed Dec. 11, 1959 2 Sheets-Sheet 1

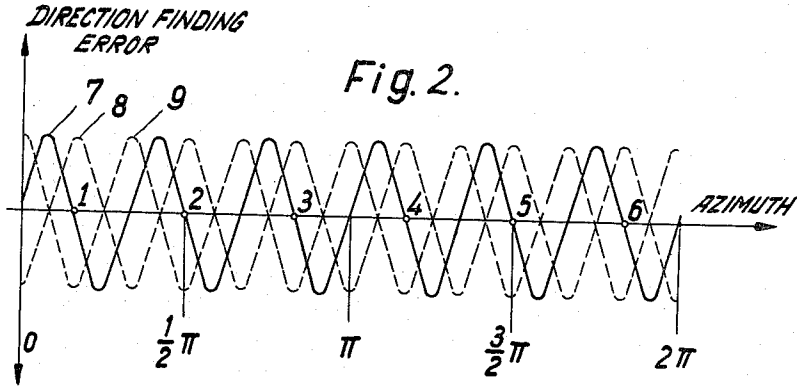


Fig. 2.

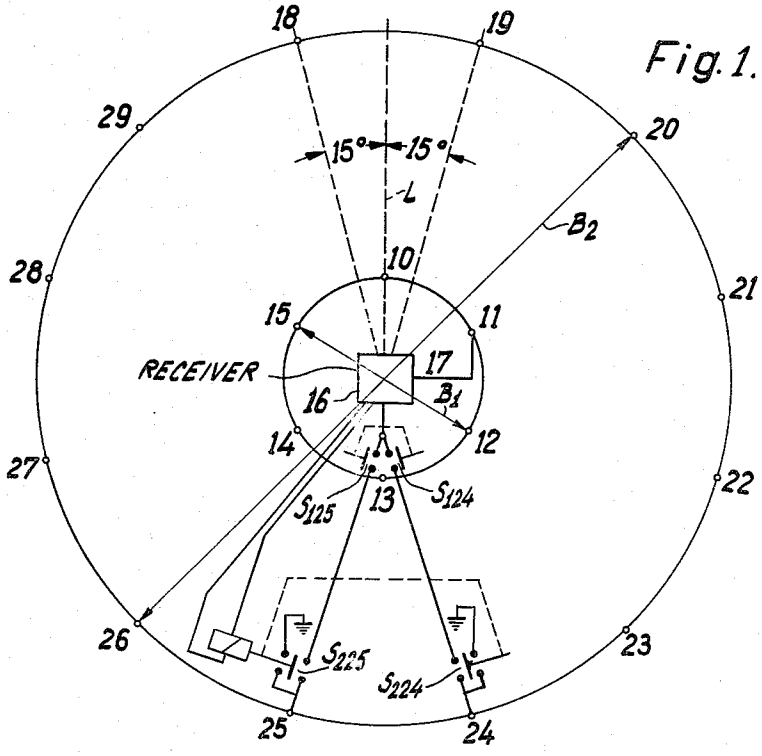


Fig. 1.

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2 Sheets-Sheet 2

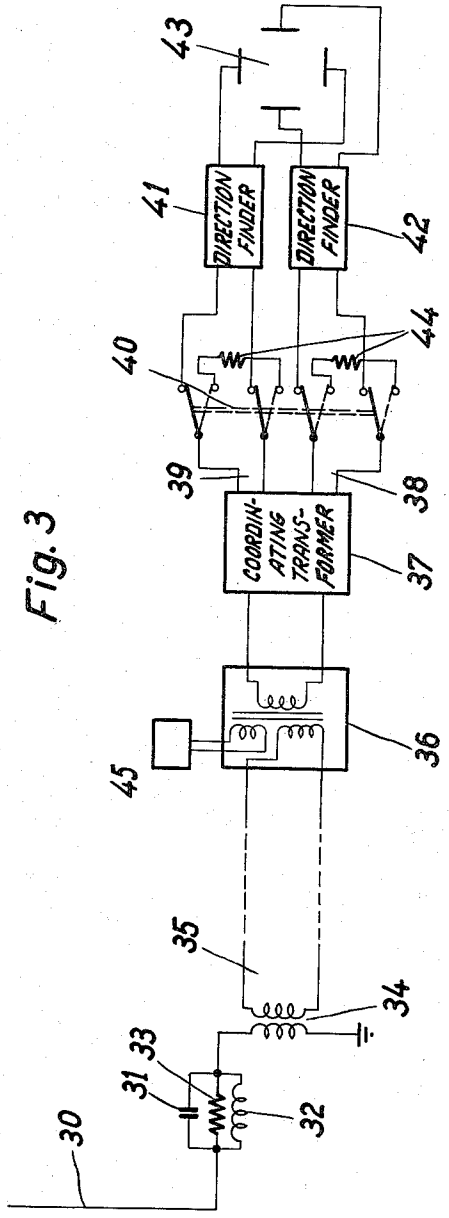


Fig. 3

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DUAL ADCOCK ANTENNA SYSTEM

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9 Claims. (Cl. 343—113)

The present invention relates to an Adcock antenna system for a wide frequency range.

It is desirable to construct Adcock antenna systems in such a manner that direction-finding operations are possible within a wide range of frequencies. No general difficulties are nowadays encountered in developing a direction-finding receiver of sufficient band width. However the frequency range to be received also depends on the selected geometrical base of the antenna system, i.e. the physical spacings of the antenna elements. An antenna system provided with a particular geometrical base can be satisfactorily used only in a relatively narrow frequency range, while in adjacent frequency ranges, the sensitivity is severely impaired. In many cases, particularly in case of a weak transmitter, such impairment of sensitivity produces very undesirable results. In order to provide direction-finding means having a sufficient band width with approximately constant sensitivity throughout the band, provision had to be made for two or more completely separated direction-finder units, which units have different geometrical antenna bases. Such an arrangement then makes it posible to carry out direction finding in various frequency ranges.

While the first-mentioned of the conventional direction-finding systems operates only inadequately in the marginal frequency ranges, wherein its efficiency is low, the other of the conventional systems using several direction finders requires a great expenditure in order to achieve a broad band width, since several complete direction-finding units have to be provided.

It is an object of the present invention to provide an Adcock antenna system by means of which direction finding, even in case of relatively weak transmitters, is made possible over a wide frequency range, because the sensitivity of the antenna system does not decrease considerably anywhere in the entire frequency range used, and for which the expenditure on equipment is moderate.

The Adcock antenna system according to the present invention is characterized by two antenna systems having different-size geometrical bases arranged concentrically with respect to each other. The outer antenna system comprises twice the number of individual antennas than the inner system, wherein two of these outer antennas are always arranged symmetrically with respect to a radial line through the center of the entire system and one of the antennas of the inner system, said antennas being angularly displaced by π/n with respect to said radial line ("n" representing the number of antennas in the outer system). In each case the two outer antennas thus arranged are connected in parallel with each other.

Still further objects and the entire scope of applicability of the present invention will become apparent from the detailed description given hereinafter; it should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

In the drawings:

FIGURE 1 is a schematic plan view of a system according to the invention.

FIGURE 2 is a diagram used in describing the elimination of error voltages by the system shown in FIGURE 1.

FIGURE 3 illustrates an output circuit for a single antenna which can be used to provide a modification of the system shown in FIGURE 1.

FIGURE 1 illustrates a field-tested embodiment of the invention. An inner antenna system includes a six-mast Adcock unit having antennas **10**, **11**, **12**, **13**, **14** and **15**. These antennas are connected to the coordinating transformer of a direction-finding receiver **16** shown in the center of this inner antenna system via lead wires such as that labeled **17**. For the sake of simplicity, only the lead wire of the antenna **11** to the direction-finding receiver is shown. In a practical embodiment, the base diameter of this Adcock system, B_1, measures 8 meters. This inner antenna system is used for the frequency range of 9 to 25 megacycles. Concentrically with this six-mast Adcock system, a further system with twelve single antennas **18**, **19**, **20**, **21**, **22**, **23**, **24**, **25**, **26**, **27**, **28** and **29** is provided. The base diameter for this system, B_2, measures 28 meters. This outer antenna system is used for direction-finding operations in the frequency range of 1.35 to 9 megacycles. The antennas **18** and **19**, **20** and **21**, **22** and **23**, **24** and **25**, **26** and **27**, **28** and **29** form pairs; and the antennas of every pair are displaced by an angle of 15° with respect to the extended radial line between the center of the systems and a single antenna of the inner system. This is shown particularly with respect to the inner antenna **10**; the outer antennas **18** and **19** are symmetrically displaced by 15°, respectively, from the extended radial line L through the antenna **10** and the common center point of the two systems. Both antennas comprising a pair, as defined above, are connected in parallel. For reasons of simplicity, however, this connection is illustrated only at the antennas **24** and **25**. The parallel connection can be provided by means of transformers having two primary windings and one secondary winding. In this case, the voltage of the received signal will be increased by the amount of $\sqrt{2}$, whereby an additional improvement of the reception is obtained. It has been found that it is advantageous to ground the antennas of whichever of the two concentric systems is not used at any specified time, and to disconnect the connecting wires of this system from the receiver. It is advantageous to provide interruption switch means for the connecting wires at the receiver as well as at the individual antennas of the outer antenna system. This is indicated by two switches S_{124} and S_{125} at the receiver and switches S_{224} and S_{225} at the antennas **24** and **25**, respectively. The switches S_{224} and S_{225} are capable of grounding their associated antennas. As this circuit is repeated and is easy to understand, all of the individual switches for the other antennas have not been illustrated. However, the switch S_{225} is shown in a representative manner as a relay operated from the central receiver unit **16**. It is advantageous to provide relays as switch means, which relays are controlled by a common master switch (not shown).

If the cross-over frequency of the two frequency ranges which are to be covered by the entire antenna system is selected in such a manner that it coincides with one end of one tuning range of the receiver, then the switch-over from the inner antenna system to the outer system, or vice versa, including all of the other necessary operations can be coupled with the band switch of the receiver.

In the following, it shall be explained why the outer system is to have twice as many antennas as the inner system: Suppose, for example, that the outer system, as shown in FIGURE 1, has only six single antennas. Practical tests in this respect have shown, however, that such an outer antenna system must comprise a reflector for

the inner antenna system, and thus adds an error to other errors already present. This additional error in direction finding amounts to one-twelfth of a cycle in the case of a six-mast Adcock. This error assumes considerable proportions so that such an arrangement of the two groups of antennas is not useful where reasonably satisfactory direction-finding conditions are desired.

It can be shown and has been proven by tests that this error of a twelfth of a cycle can be cancelled if the number of antennas of the outer system is doubled, and if these antennas are arranged in pairs, as shown in FIGURE 1, symmetrically with respect to the extended radial line between the common center of the inner and the outer systems and one of the antennas of the inner antenna system, whereby the antennas comprising one outer pair are displaced with respect to this radial line by an angular magnitude of π/n (wherein "n" equals the number of outer antennas), i.e., in the case of a six-mast Adcock, by 15° with the two antennas thus arranged connected in parallel.

FIGURE 2 illustrates in a six-mast Adcock inner antenna system, as shown in FIGURE 1, how the occurring error of a twelfth of a cycle is cancelled. The curves of various errors are shown therein on Cartesian coordinates. The six antennas of the inner antenna system are indicated by the reference numerals **1** to **6**. If only six outer antennas are mounted on a larger base circle concentrically of this inner antenna system in such a manner that they are positioned on the extension of a radial connecting line between the center and a single Adcock antenna of the inner system, the inner Adcock system then will produce a direction-finding error curve indicated by the reference numeral **7**. This error appears in addition to the other minor errors inherently present in every Adcock system. As stated above, this error is due to the reflection of the outer anntena system. If, however, instead of each single antenna of this outer system, two antennas are provided, as shown in FIGURE 1, and if they are displaced symmetrically to the left and right by an angular displacement of 15° with respect to the said radial line, then the inner system produces two error curves each having a twelfth of a cycle, as illustrated in dashed lines in FIGURE 2 and indicated by numerals **8** and **9**. These errors are displaced in phase with respect to each other and with regard to the direction-finding error curve **7**, not present any more. As the angular displacement of the antennas with respect to the original position amounts to 15° in each case, the direction-finding error curves **8** and **9** are displaced in phase by exactly 180°, i.e., they cancel each other out. Such an arrangement, therefore, achieves the elimination of the presently considered direction-finding errors, and the two concentrically arranged antenna systems are at least equivalent in value to two separately arranged systems.

In addition to this, a further improvement in the outer antenna system is obtained: It is well known that the direction-finding error of an Adcock system in general can be decreased and for one frequency can even be completely eliminated, if to each single antenna of an Adcock system a second antenna is added and is connected in parallel with the former. The most favorable angle of horizontal displacement for the six-mast Adcock system, in general, is an angle of 35°. In the arrangement described above, the angle between two parallel antennas of the outer Adcock system is 30°. However, even this angle between these two antennas is already sufficient to bring about a decrease in the direction-finding error, even though not to the same extent as in the case of an angle of 35°. Thus, in addition to the elimination of the error of a twelfth of a cycle of the inner antenna system, the arrangement according to the present invention provides for the compensation of another direction-finding error in the outer system. The efficiency of this system is, thus, even better with respect to the normal Adcock system.

Another measure can be taken to further improve the reception by avoiding the undesired mutual couplings of the connecting wires of the individual systems to the direction-finding receiver. This measure represents a further development of the present invention and will be described below. This improvement has the advantage that the electrical connections to the switches of the single antennas as well as the relays themselves located at the antennas can be eliminated. Moreover, with the arrangement according to this further development, it is possible to use the two antenna systems with two separate direction-finding receivers, which may be of interest in some cases.

In the arrangement of the system according to this further development of the present invention, a filter member is provided between the decoupling point of every individual antenna of the outer antenna system and the output transformer, by means of which member at least the approximate operating frequency range of the inner antenna system is eliminated. Moreover, means are provided such that in case of the use of the two antenna systems with only one direction-finding receiver, a resistance may be inserted across the connecting wires of whichever antenna system at that moment is disconnected from the direction-finding receiver, which resistance approximately equals the input resistance of the direction-finding receiver.

The two concentric antenna systems of the entire Adcock antenna system can also be operated with two direction-finding receivers, whereby each antenna system is connected directly to one of the direction-finding receivers. As described above, filters are provided between the decoupling points of the single antennas of the outer antenna system and the output transformers, by means of which filters the frequencies for which the other system is provided will be eliminated. This filter may be a band-pass circuit, for instance, designed for a band of corresponding width and having a correspondingly selected mean frequency. If the inner antenna system operates, for instance, between 9 and 25 megacycles, then the selected band width of the blocking circuit would be approximately 15 megacycles, and the resonant frequency of the circuit would be approximately between 15 and 20 megacycles. In place of a band-pass circuit it is, of course, possible to use a low-pass filter which, for example, excludes all frequencies above 9 megacycles but, on the other hand, permits all frequencies below 9 megacycles to pass through.

Moreover, by the use of the above two antenna systems together with one direction-finding receiver, the interruption of the transmission lines to the individual antennas of the outer system and also the grounding of those antennas of the system not in use are eliminated. This measure, according to the further development of the present invention, therefore, makes possible a reduction in the expenditure involved in connecting wires and switching devices. Admittedly, when using the two antenna systems with a single direction-finding receiver in place of interrupting and grounding, it is necessary to connect a resistance to the transmission line which resistance corresponds approximately to the input resistance of the direction-finding receiver. This measure can, however, be carried out at the location of the direction-finding receiver, thus making it considerably simpler than having to carry out various switching measures at the individual antennas. It has been shown that this measure is sufficient to eliminate any harmful influences of the transmission lines upon each other, i.e., it is then unnecessary to provide any additional switching for the inner antenna circuit.

The construction of the antenna system according to the further development of the present invention is shown in FIGURE 3 in the example of a single antenna of the outer circuit. The inner system of the two antenna systems is to be a six-mast Adcock. Thus, twelve antennas are necessary in the outer antenna system, as shown in FIGURE 1, each pair of the antennas of the outer system

being connected in parallel. One of these twelve antennas is illustrated in FIGURE 3 and is designated by the reference numeral 30. It may be an ordinary rod antenna or, as frequently employed nowadays, a broader-banded subdivided vertical wire antenna, in which case a dipole is arranged between the individual components of this vertical wire antenna.

The foot of the antenna 30 is connected to a filter circuit comprising a capacity 31, an inductance 32, and a resistance 33. The output of the filter circuit is connected to the primary winding of an output transformer 34, which winding is grounded at its other end. A balanced transmission line 35 leading to the direction-finding receiver is connected to the secondary winding of the transformer 34. The transmission line 35 leads first to a network 36 in which the antenna 30 and the other adjacent antenna of the pair in the outer antenna system are connected in parallel. The network 36 may be a transformer with two primary windings and one secondary winding. One of the primaries is connected to the line 35, while the other one is connected to a unit 45 which represents the input circuit of the adjacent antenna and includes elements corresponding to the elements 30–34. The two parallel-connected antennas now operate as a single antenna. Thus, the outer antenna circuit with twelve single antennas also functions as a six-mast Adcock. The six antenna pairs are connected to a coordinating transformer 37 in a manner known per se. For the sake of simplicity, the drawing does not show all of the other transmission lines. Also, all of the other antennas for the member 37 are not illustrated. However, they are similar to the one shown in the drawing.

The coordinating transformer 37 supplies at its outputs 38 and 39 two output voltages corresponding to Cartesian coordinates. If the outer antenna system is employed, the two output voltages are fed via switches 40, in the position as shown, to channels 41 and 42 of a two-channel direction-finder. The two outputs of the channels drive the deflection plates of a cathode ray tube 43 in a manner known per se. The switching elements 40 are located at the receiver. If the outer antenna system is not in use, then it is cut off from the channels 41 and 42 of the direction-finding receiver by switching-over of the switching device 40 into the position shown in dashed lines, and the inner antenna system (not shown) is then connected to these channels. In this position, in which the outer system is disconnected from the receivers, each of the outputs of the coordinating transformer is shunted by a resistance 44. The ohmic value of these resistances corresponds to the input resistance of the associated channel of the direction-finding receiver. In many cases the coordinating transformer is structurally combined with the direction-finding receiver. Thus, the direction-finding receiver would have to be changed to enable the mounting of the switching device 40. However, instead of shunting the transmission line behind the coordinating transformer, it is alternatively possible to connect the switching device 40 before the coordinate transformer and thereby shunt the individual transmission lines by means of a resistance of properly transformed value.

Similarly, when the outer antenna system is in use, the outputs of the coordinating transformer for the inner antenna system are shunted by means of corresponding resistances provided in a manner similar to the one shown here for the outer system. The connection of a filter circuit or low-pass filter to the antenna, and the shunting of the corresponding outputs of the coordinating transformers by a resistance corresponding to the input resistance of the direction-finding receiver, eliminates all undesired mutual influences of the two antenna systems upon each other. In addition to this, it is also possible that each of the two antenna systems can be operated simultaneously with a direction-finding receiver assigned to each. For this purpose, it is only necessary to provide, for one of the antenna systems, a third switch position of the switching device 40, in which position, for instance, the outputs of the coordinating transformer 37 of the outer system are connected to a second direction-finding receiver, while the inner antenna system is connected to the channels 41 and 42 of the first direction-finding receiver.

By means of this arrangement, not only a reduction in expenditure has been achieved, but also a further possibility of using the antenna system has been created.

We claim:

1. A dual Adcock antenna arrangement for obtaining coverage over two frequency ranges, comprising coordinating transformer means having receiver means, an inner system of antennas disposed normal to a reference plane and equally spaced from a center point lying in said plane, and inner transmission line means for connecting said antennas with said coordinating means; and an outer system of antennas arranged normal to said plane and equally spaced from said center point by a distance greater than the spacing of the antennas of the inner system, there being twise as many antennas in the outer system and these antennas being substantially equally spaced and grouped in pairs with the antennas of each pair symmetrically disposed on opposite sides of a line drawn in the plane through said center point and one of the inner antennas, and outer transmission line means for connecting the paired antennas mutually in parallel and connecting each pair with said coordinating transformer means.

2. In an Adcock arrangement according to claim 1, switch means in said transmission line means to connect one system and to ground the individual antennas of the other system and to interrupt the conductors of the associated transmission lines to said receiver means.

3. In an Adcock arrangement according to claim 2, said switch means including a switch for the interruption of each conductor of the non-connected transmission line means both at the receiver means and also at each individual antenna.

4. In an Adcock arrangement according to claim 2, relays comprising said switch means and said relays being controlled by central selector switch means.

5. In an Adcock arrangement according to claim 4, said receiver means having a range switch and said central switch means being coupled with the range switch of the receiver.

6. In an Adcock arrangement according to claim 1, said outer transmission line means comprising a transformer associated with each pair of outer antennas and having two primary windings each connected to one antenna of the pair, and having one secondary winding connected to conductor means connected with a coordinating transformer means.

7. In an Adcock arrangement according to claim 1, filter means connected between each individual antenna of at least one antenna system and its associated coordinating transformer means for attenuating at least the range of frequencies to which the other antenna unit is responsive; resistor means having a value substantially equaling the input resistance of said receiver means; and selector switch means for connecting the output from one antenna system to said receiver means and connecting the output of the other antenna system to said resistor means.

8. In an Adcock arrangement according to claim 7, said filter means each comprising a band-pass filter tuned to the range of frequencies to which the associated system is responsive.

9. In an Adcock arrangement according to claim 7, said filter means each comprising a low-pass filter connected to each antenna in the outer pairs and cutting off at the upper frequency of the lower-frequency range.

No references cited.