# PATENT SPECIFICATION

305,250

Application Date: Oct. 3, 1927. No. 26,086/27.

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Complete Left: July 3, 1928.

Complete Accepted: Feb. 4, 1929.

PROVISIONAL SPECIFICATION.

## Improvements in and relating to Apparatus adapted for use in Radio-telegraphic Direction Finding and for similar purposes.

We, ROBERT ALEXANDER WATSON WATT and LABOUCHERE HILLYER BAINBRIDGE-BELL, both British subjects, both of The Radio Research Station of the Department of Scientific and Industrial Research, Ditton Park, Langley, in the County of Buckingham, do hereby declare the nature of this invention to be as follows:—

This invention relates to apparatus adapted for use in radio-telegraphic direction finding and for similar purposes in which the determination of the direction of arrival of magnetic waves is to be effected.

Some of the apparatus and arrangements of apparatus for use for the purpose in question which have been proposed suffer from the limitation that their indications exhibit an ambiguity of 180°. This is the case, for instance, with the apparatus described and claimed in the Specification No. 252,263 unless special provision is made and it is indicated in the said specification that the desired result may be secured by the introduction of a deflecting force operating on the beam of cathode rays by coupling electromagnetic or electrostatic devices, connected to a non-directional aerial, directly or by way of an amplifier with or without phase-controlling devices to the oscillograph.

The main object of the present invention is to provide improved means for securing the results above indicated.

The invention consists broadly in employing as part of the direction finding system one or more non-directional aerials which are coupled directly or by way of triode or other amplifiers to the indicating instrument in such manner that the deflectional sensitivity or clearness of response of the indicating instrument depends on the electromotive forces present in the non-directional aerial.

Preferably in accordance with the invention the sensitivity or the clearness of response may be made to depend on the instantaneous phase of the electromotive forces in the non-directional aerial.

The control may, for example, in the case where the indicating instrument is a cathode ray oscillograph, be effected by modification of the ionic content or the ionic velocity of the indicating beam.

Such modification may be produced by operating on the filament current of the oscillograph, on the space charge in the inter-electrode space, on the accelerating voltage driving the beam or on the magnetic or electric fields traversed by the beam.

In one arrangement of apparatus in accordance with the invention adapted to remove the ambiguity as to the direction of arrival of electromagnetic waves, the electromotive force induced in a separate vertical aerial or in the lead joining the directional loops to earth, as shown in the Specification No. 252,263, is employed.

This electromotive force, called hereinafter the "non-directional electromotive force," is brought by methods of phase shifting substantially into phase or into anti-phase with the electromotive force in the directional aerials and is caused to modulate either the velocity of the ionic stream or its directional sensitivity or its point of focus or a combination of any or all of these.

For example in accordance with the invention the non-directional aerial system may be coupled through a triode amplifier and phase-adjusting means to a coil which may be coupled through a triode amplifier to a resistance in series with the anode circuit of the oscillograph.

In an alternative arrangement the resistance above referred to is inserted between the anode of the oscillograph and the leak resistances connecting the individual deflector plates to the anode of the oscillograph.

In a further alternative the equivalent of the resistance in question is inserted

[Price 1/-]

between the cathode of the oscillograph and a control electrode or grid between the cathode and anode.

Instead of arrangements such as those described above the coil coupled to the non-directional aerial is connected directly or by way of amplifiers to a coil which produces an axial magnetic field which also controls the sensitivity or focal distance of the ionic beam.

With all of these arrangements the sensitivity, brightness of fluorescence or focal distance differ according to the instantaneous sense of the voltage in the non-directional aerial and therefore with the instantaneous phase of the incident wave train.

The operation of apparatus in accordance with the invention, in which the voltages induced in the non-directional aerial are employed for modulating the velocity of the ions and the indicating beam, may be explained by the following example, in which it is assumed that the apparatus is connected so that during the half-cycle of the directional electromotive force which deflects the beam toward the north plate the non-directional electromotive force increases the velocity of the stream and during the half-cycle of the directional electromotive force which directs the beam toward the south plate the non-directional electromotive force decreases the velocity of the stream. With such an arrangement a signal coming from the north of the east-west line through the receiver will cause the indicating spot on the oscillograph to be brighter during the movement northward than during the movement to the south, whereas if a signal is coming from the south of the east-west line the phase difference between the directional and the non-directional electromotive force is changed by 180° as compared with the preceding case, and the non-directional electromotive force therefore increases the velocity of the stream during the southward movement of the indicating spot as compared with the northward movement. Consequently, if the brightness of the indicating spot is observed the sense as well as the direction of arrival will be determined.

The frequency of oscillation of the fields and voltages applied to the oscillograph need not be that of the original wave train but may be derived from that frequency by known processes such as heterodyning and rectification, detection or demodulation.

The amplifying or coupling arrangements between the non-directional aerial and the circuits of the indicating element should preferably include devices for deriving from the original wave form a wave which is substantially flat topped so that the effective sensitivity, brightness or focal distance may remain constant over a considerable portion of each half wave.

The device for effecting this change of wave shape may for example be a triode adjusted to produce limitation of output voltage by the known methods of temperature or space charge limitation.

As will be understood, the above detailed description is furnished for the purpose of indicating the nature of the invention which is therefore not to be regarded as limited to the particular constructions or arrangements described in detail.

Dated this 3rd day of October, 1927.
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COMPLETE SPECIFICATION.

## Improvements in and relating to Apparatus adapted for use in Radio-telegraphic Direction Finding and for similar purposes.

We, ROBERT ALEXANDER WATSON WATT and LABOUCHERE HILLYER BAINBRIDGE-BELL, both British subjects, both of The Radio Research Station of the Department of Scientific and Industrial Research, Ditton Park, Langley, in the County of Buckingham, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to apparatus adapted for use in radio-telegraphic direction finding and for similar purposes in which the determination of the direction of arrival of magnetic waves is to be effected.

Some of the apparatus and arrangements of apparatus for use for the purpose in question which have been proposed suffer from the limitation that their indications exhibit an ambiguity of 180°. This is the case, for instance, with the apparatus described and claimed in the

Specification No. 252,263 unless special provision is made and it is indicated in the said specification that the desired result may be secured by the introduction of a deflecting force operating on the beam of cathode rays by coupling electromagnetic or electrostatic devices, connected to a non-directional aerial, directly or by way of an amplifier with or without phase-controlling devices to the oscillograph.

The main object of the present invention is to provide improved means for securing the results above indicated.

The invention consists broadly in a radio-telegraphic apparatus or arrangement comprising a non-directional aerial and a directional aerial system or an aerial system which can serve both purposes and means which depend on the electromotive forces present in the non-directional aerial or in the non-directional portion of a combined aerial for removing ambiguity of the directional indications given by the indicating element, namely the ionic beam in a cathode ray oscillograph.

Thus, in accordance with the invention, there may be employed as part of the direction finding system one or more non-directional aerials which are coupled directly or by way of triode or other amplifiers to the indicating instrument in such manner that the deflectional sensitivity or clearness of response of the indicating instrument depends on the electromotive forces present in the non-directional aerial.

Preferably in accordance with the invention the sensitivity or the clearness of response may be made to depend on the instantaneous phase of the electromotive forces in the non-directional aerial.

The control may, for example, be effected by modification of the ionic content or the ionic velocity of the indicating beam.

Such modification may be produced by operating on the filament current of the oscillograph, on the space charge in the inter-electrode space, on the accelerating voltage driving the beam or on the magnetic or electric fields traversed by the beam.

In one arrangement of apparatus in accordance with the invention adapted to remove the ambiguity as to the direction of arrival of electromagnetic waves, the electromotive force induced in a separate vertical aerial or in the lead joining the directional loops to earth, as shown in the Specification No. 252,263, is employed.

This electromotive force, called hereinafter the "non-directional electromotive force," is brought by methods of phase shifting substantially into phase or into anti-phase with the electromotive force in the directional aerials and is caused to modify either the velocity of the ionic stream or its directional sensitivity or its point of focus or a combination of any or all of these.

For example in accordance with the invention the non-directional aerial system may be coupled through a triode amplifier and phase-adjusting means to a coil which may be coupled through a triode amplifier to a resistance in series with the anode circuit of the oscillograph.

In an alternative arrangement the resistance above referred to is inserted between the anode of the oscillograph and the leak resistance connecting the individual deflector plates to the anode of the oscillograph.

In a further alternative the equivalent of the resistance in question is inserted between the cathode of the oscillograph and a control electrode or grid between the cathode and anode.

In a further alternative a transformer to whose primary winding is applied an electromotive force controlled by the non-directional electromotive force has its secondary winding in the filament circuit, so that the temperature of the filament and consequently, under known conditions, the emission of electrons, is modified in accordance with the non-directional electromotive force.

Instead of arrangements such as those described above the coil coupled to the non-directional aerial is connected directly or by way of amplifiers to a coil which produces an axial magnetic field which also controls the sensitivity or focal distance of the ionic beam.

Certain arrangements in accordance with the invention are illustrated diagrammatically and by way of example in the accompanying drawings, in which:—

Figure 1 illustrates one arrangement for carrying the invention into effect, and

Figures 2, 3, and 4 illustrate alternative arrangements, while

Figure 5 illustrates, by way of example, the arrangement of one complete installation in accordance with the invention.

In Figure 1, 1 indicates the non-directional aerial system coupled through triode amplifiers 2 and 2*a* to a coil 3 which is coupled through a triode amplifier 4 to a resistance 5 arranged in series in the anode circuit of the oscillograph 7.

In Figure 2 the resistance 6 is inserted between the anode 7 of the oscillograph and the leak resistances 8 connected to the deflector plates 9 of the oscillograph.

In Figure 3 the resistance 6 is inserted

between the cathode of the oscillograph and the control electrode or grid 10 between the cathode and anode of the oscillograph, the plates of which in this case are indicated also by the reference 9.

In Figure 4 the coil 11 is arranged so as to produce an axial magnetic field which controls the sensitivity or focal distance of the ionic beam of the oscillograph, the deflector plates of which in this case also are indicated by the reference 9.

Figure 5 shows schematically and by way of example only the complete circuital arrangements of an installation in accordance with one of the alternative arrangements already described, namely that in which the ionic content of the beam is modified by means of a control electrode whose potential is controlled by the non-directional electromotive force. Referring to Figure 5, $A_N$ and $A_E$ represent diagrammatically, tuning, amplifying, filtering, frequency changing and phase adjusting means, known in the art, associated with the directional aerials, while $A_V$ represents means of similar character associated with the non-directional aerial system. Reference 10 represents the control electrode or grid, while the other references are as in Figures 1 to 4.

With all of these arrangements the sensitivity, brightness of fluorescence or focal distance differ according to the instantaneous sense of the voltage in the non-directional aerial and therefore with the instantaneous phase of the incident wave train.

The operation of apparatus in accordance with the invention, in which the voltages induced in the non-directional aerial are employed for modifying the velocity of the ions in the indicating beam, may be explained by the following example, in which it is assumed that the apparatus is connected so that during the half-cycle of the directional electromotive force which deflects the beam toward the north plate the non-directional electromotive force increases the velocity of the stream and during the half-cycle of the directional electromotive force which directs the beam toward the south plate the non-directional electromotive force decreases the velocity of the stream. With such an arrangement a signal coming from the north of the east-west line through the receiver will cause the indicating spot on the oscillograph to be brighter during the movement northward than during the movement to the south whereas if a signal is coming from the south of the east-west line the phase difference between the directional and the non-directional electromotive force is changed by 180° as compared with the preceding case, and the non-directional electromotive force therefore increases the velocity of the stream during the southward movement of the indicating spot as compared with the northward movement. Consequently, if the brightness of the indicating spot is observed the sense as well as the direction of arrival will be determined.

The frequency of oscillation of the fields and voltages applied to the oscillograph need not be that of the original wave train but may be derived from that frequency by known processes such as heterodyning and rectification, detection or demodulation.

The amplifying or coupling arrangements between the non-directional aerial and the circuits of the indicating element should preferably include devices for deriving from the original wave form a wave which is substantially flat topped so that the effective sensitivity, brightness or focal distance may remain constant over a considerable portion of each half wave.

The device for effecting this change of wave shape may for example be a triode adjusted to produce limitation of output voltage by the known methods of temperature or space charge limitation.

As will be understood, the above detailed description is furnished for the purpose of indicating the nature of the invention and for the purpose of illustrating suitable methods of carrying the same into effect which is therefore not to be regarded as limited to the particular constructions or arrangements described in detail.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A radio-telegraphic apparatus or arrangement comprising a non-directional aerial and a directional aerial system or an aerial system which can serve both purposes and means which depend on the electromotive forces present in the non-directional aerial or in the non-directional portion of a combined aerial for removing ambiguity of the directional indications given by the ionic beam of a cathode ray oscillograph.

2. A radio-telegraphic apparatus or arrangement as claimed in Claim 1 in which is employed as part of the direction finding system one or more non-directional aerials which are coupled directly or by way of triode or other amplifiers to the indicating instrument in such manner

that the deflectional sensitivity or clearness of response of the ionic beam of a cathode ray oscillograph depends on the electromotive forces present in the non-directional aerial.

3. A radio-telegraphic apparatus or arrangement as claimed in either of the preceding claims in which the sensitivity or clearness of response is made dependent on the instantaneous phase of the electromotive forces in the non-directional aerial.

4. A radio-telegraphic apparatus or arrangement as claimed in any of the preceding claims in which an electrode or grid is used for modifying the ionic content or ionic velocity of the indicating beam.

5. A radio-telegraphic apparatus or arrangement as claimed in any of the preceding claims in which the non-directional component modifies the filament current of the cathode ray oscillograph.

6. A radio-telegraphic apparatus or arrangement as claimed in any of the preceding claims in which the non-directional component modifies the accelerating voltage acting on the ionic beam, without the introduction of additional electrodes.

7. A radio-telegraphic apparatus or arrangement as claimed in any of the preceding claims in which the non-directional component modifies the electric or magnetic fields, other than the deflecting fields, affecting the ionic beam.

8. The improved radio-telegraphic apparatus or arrangements substantially as hereinbefore described and as illustrated in and by the accompanying drawings.

Dated this 3rd day of July, 1928.

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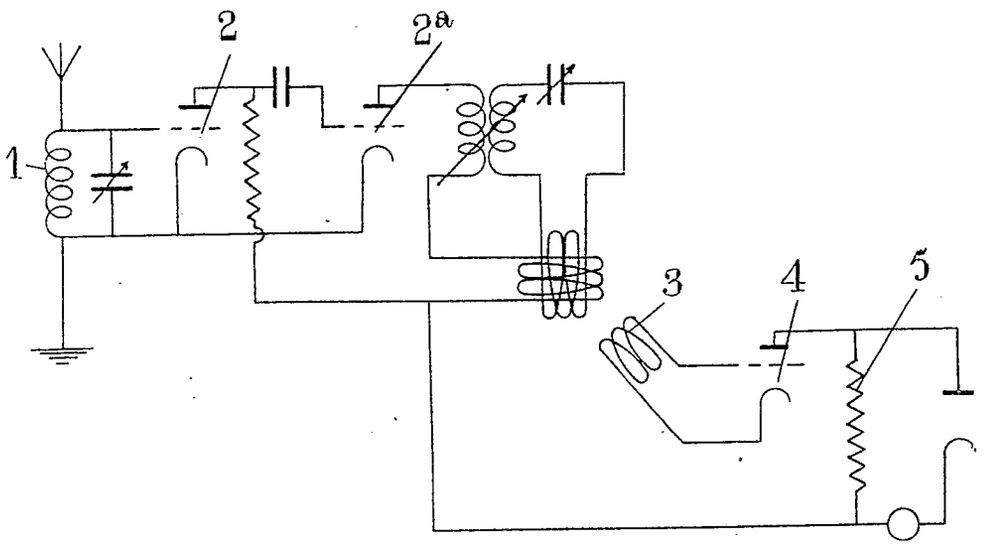



Fig. 1.

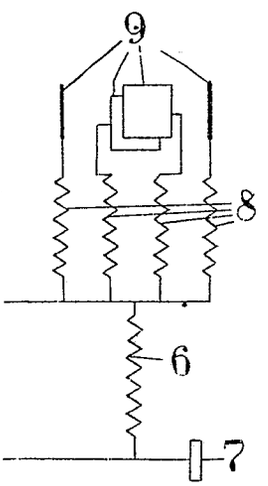



Fig. 2.

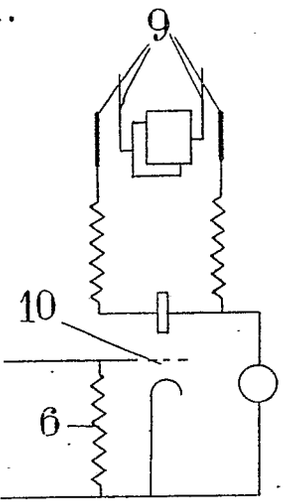



Fig. 3.

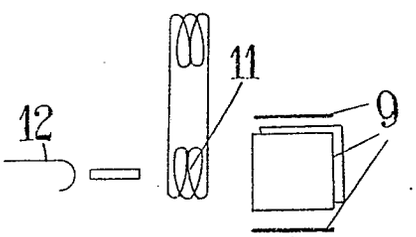
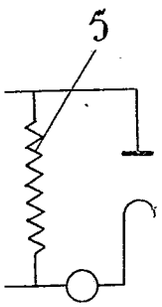
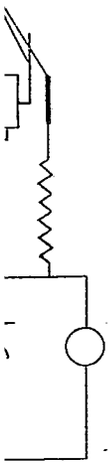



Fig. 4.



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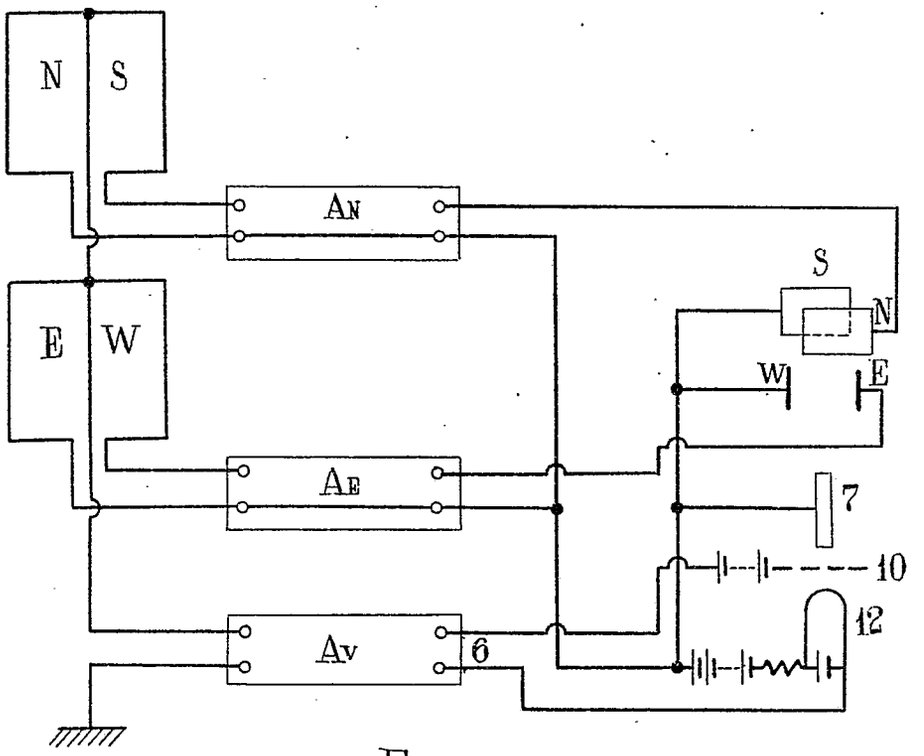


Fig. 5.

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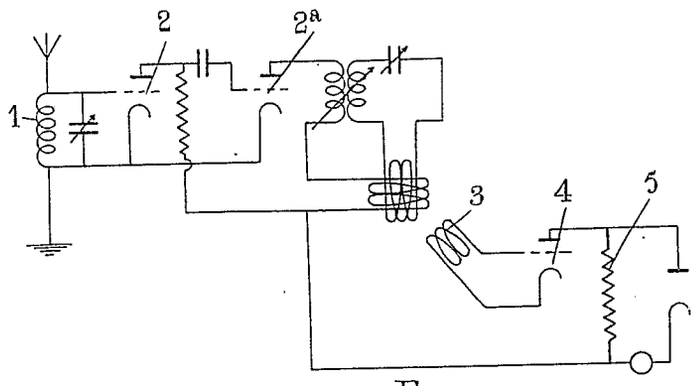


Fig. 1.

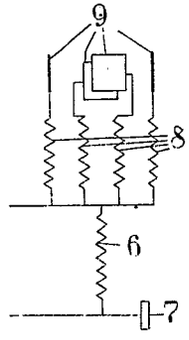


Fig. 2.

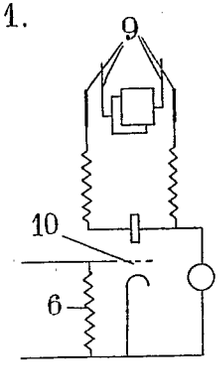


Fig. 3.

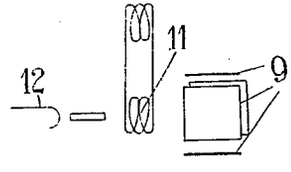


Fig. 4.

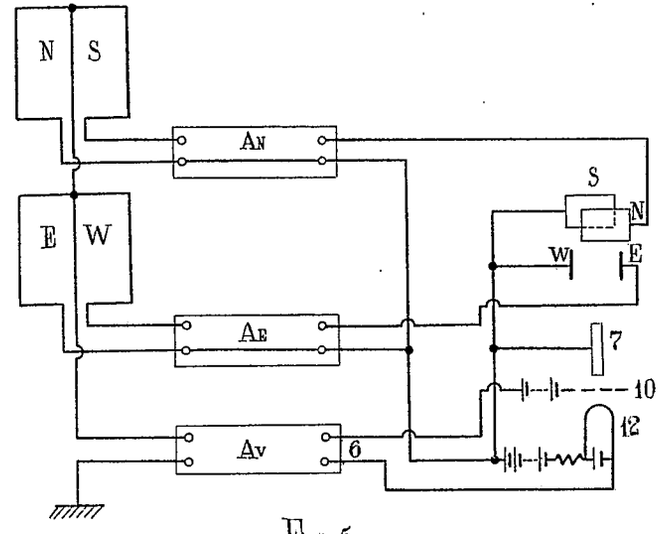


Fig. 5.

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