Sept. 3, 1940. C. F. A. WAGSTAFFE 2,213,874

WIRELESS DIRECTION FINDING SYSTEM

Filed May 21, 1938 2 Sheets-Sheet 1

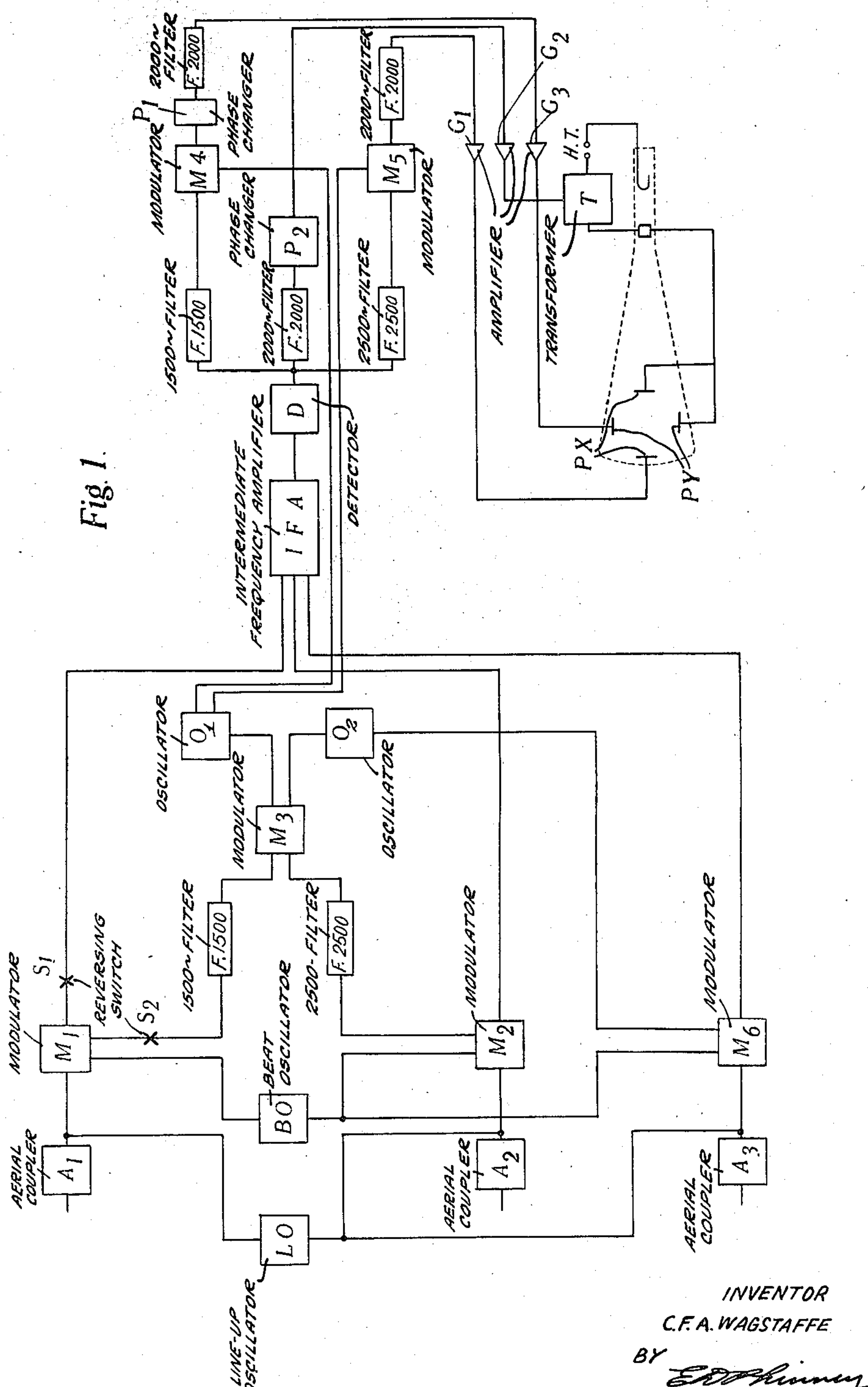

Fig. 1.

INVENTOR
C.F.A. WAGSTAFFE
BY [signature]
ATTORNEY

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Fig. 3.

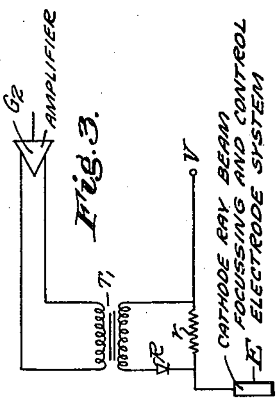


Fig. 4.

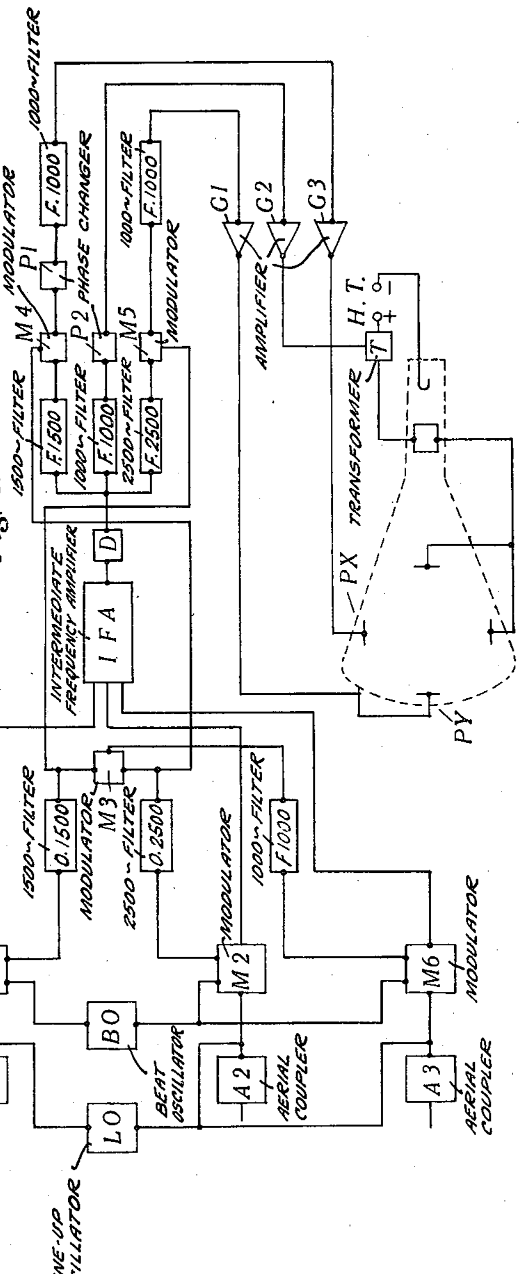
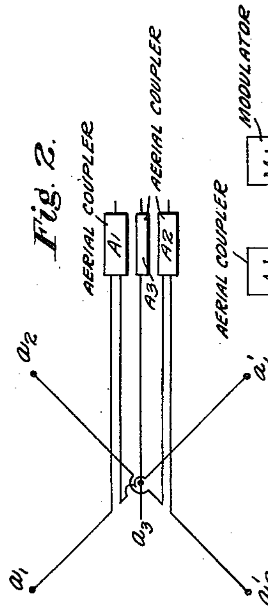


Fig. 2.



INVENTOR
C.F.A. WAGSTAFFE
BY [signature]
ATTORNEY

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WIRELESS DIRECTION FINDING SYSTEM

Charles Frederick Allen Wagstaffe, London, England, assignor to International Standard Electric Corporation, New York, N. Y.

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14 Claims. (Cl. 250—11)

This invention relates to wireless direction finding systems and more particularly to such systems of the kind in which the signal waves are received on a plurality of fixed directional aerial systems which are so positioned that their respective directions of maximum pick-up are arranged at an angle to one another.

In apparatus of this type, in which for example, the bearing is indicated directly on a cathode ray oscillograph, separate amplifying channels are usually provided for each aerial system and each is associated with a deflecting system of the oscillograph. This arrangement suffers from two great disadvantages (*a*) the great difficulty of balancing and maintaining in balance, both as regards gain and phase shift, the two amplifying channels; and (*b*) the practical impossibility of applying automatic gain control to the receiving system.

The main object of the present invention is the provision of a system which will enable one amplifying channel to be used for amplifying the signal waves from two or more aerial systems and thus to obviate the above-mentioned difficulties.

According to the invention the signal waves received from each aerial system are passed to a modulating device wherein they are modulated each at a different sub-frequency, the combined modulated outputs being then amplified in a common high frequency amplifier from the output of which the sub-frequency components are selected, and used to actuate a device for indicating the direction of the signal waves incident upon the aerial systems, which device may, for example, comprise a cathode ray oscillograph.

In a preferred method of carrying out the invention the incoming signal waves are subjected also to modulation by a beating oscillator in order to permit of their amplification by an intermediate frequency amplifier.

The invention will be better understood from a reading of the following detailed description taken in conjunction with the accompanying drawings in which:

Fig. 1 shows schematically one embodiment of the invention;

Fig. 2 shows the arrangement of the aerial systems of the system of Fig. 1;

Fig. 3 shows a portion of the arrangement of Fig. 1 modified to provide a simultaneous indication of the bearing and sense of an incoming signal; and

Fig. 4 is a schematic circuit diagram of another system according to the invention.

Referring first to Figs. 1 and 2, a_1, a'_1 and a_2, a'_2 are the two pairs of aerials of an Adcock system. a_3 is a fifth central aerial used for the determination of sense. A_1, A_2, A_3 are aerial coupling devices. M1, M2 . . . M6 are modulating devices of any known type. F. 1500, F. 2000 and F. 2500 are filters of known type for selecting respectively frequencies of 1500, 2000 and 2500 cycles per second. O_1 and O_2 are oscillators for generating waves of 500 and 2000 cycles per second respectively. BO is the ordinary beating oscillator of a superheterodyne receiver. I. F. A. is the intermediate frequency amplifier of a superheterodyne, D is a rectifier or detector, P1 and P2 are phase-shifting networks, and G1, G2, G3 are low frequency amplifiers. PX and PY are the deflector plates of a cathode ray oscillograph. T is a transformer through which the output of amplifier G2 is injected into the high tension supply of the oscillograph. LO is an oscillator for supplying a local signal for lining up the equipment.

The operation of the system is as follows:

The oscillators O_1 and O_2 supply the modulator M3 from the output of which the intermodulation frequencies of 1500 and 2500 cycles per second are selected by the filters F. 1500 and F. 2500.

The signal from A1 passes to the modulator M1 where it is modulated by the heating oscillator BO and also by a frequency of 1500 c. p. s. from the filter F. 1500. The component of the output from the modulator M1 consisting of a carrier of intermediate frequency together with its two side bands corresponding to 1500 c. p. s. is selected and passed to the amplifier I. F. A.

A similar sequence of operations occurs in the case of the signal from A2 with the one difference that the second modulating frequency is 2500 c. p. s. instead of 1500 c. p. s. so that the input, in this case, into the amplifier I. F. A. is a carrier of the same frequency as before but having side bands corresponding to 2500 c. p. s. It can be shown that if a straight line detector is used at D, say a diode, and the signals entering M1 and M2 from A1 and A2 are in phase (the beating oscillations supplied from BO to M1 and M2 being in phase) the demodulated outputs from the detector D at 1500 c. p. s. and 2500 c. p. s. are respectively proportional to the magnitudes of the signals from A1 and A2 (though the ratio of the amplitudes of these two low frequencies may not be equal to the ratio of the signals from A1 and A2).

The two output frequencies 1500 c. p. s. and 2500 c. p. s. from the detector D are selected by filters F. 1500 and F. 2500 and are passed to modulators M4 and M5 respectively, in which they are modulated by a current of 500 c. p. s. from the oscillator 0.500. From modulator M4 the sum modulation product of 2000 c. p. s. and from M5 the difference modulation product, also 2000 c. p. s. are selected by the filters shown. The output from M4 passes through a phase changing network P_1, filter F. 2000 and amplifier G3 and then on to one pair of the oscillograph deflector plates, say PX. The output from M5 passes in a similar manner over a filter F. 2000 to the PY plates of the oscillograph except that it does not pass through any phase changing network. The network P_1 is adjusted so that the phase change in it plus the sum of the phase changes in the two 1500 c. p. s. filters, is equal to the sum of the phase changes in the two 2500 c. p. s. filters. It can be arranged by the design of the filters and phase shifting circuit that the total phase shift in the 1500 c. p. s. circuit, while not remaining constant with frequency, does remain closely the same as that for the 2500 c. p. s. circuit over an appreciable band of frequencies, (say from 50 c. p. s. below to 50 c. p. s. above the mean frequencies).

It will be seen that the two frequencies 1500 c. p. s. and 2500 c. p. s. for modulation in M1 and M2 are produced not by oscillators of these frequencies but by intermodulation of the frequencies 500 c. p. s. and 2000 c. p. s. in the modulator M3. The 500 c. p. s. oscillator is then also used to supply the modulators M4 and M5.

The advantage of this arrangement is that if the signals from the aerials, arriving at the modulators M1 and M2 are in phase, the outputs from M4 and M5 are precisely equal in frequency and phase whatever variations occur in either of the oscillators (within the limits as regards phase imposed by the filters, previously mentioned). It should be noted that the frequency of the outputs from M4 and M5 will be that of the oscillator O_2.

The voltages applied to the plates of the oscillograph, being of the same frequency and in phase, produce a line on the oscillograph screen. During the lining up operation carried out by means of the oscillator LO, which applies signals, equal in magnitude and phase, to M1 and M2, the amplifiers G1 and G3 are regulated for gain to give a line on the oscillograph forming an angle of 45° with each of the deflecting axes of the oscillograph. This of course corresponds to a signal arriving in a direction 45° to either of the diagonals of an Adcock aerial system.

After this lining up has been carried out the apparatus is ready for observing bearings, for it is clear that the deflection, sinusoidal with respect to time, of the oscillograph spot along the PX deflection axis is proportional to the signal from A_1 and the aerial system a_1, a_1 and that along the PY axis is proportional to the signal from A_2 and the aerial system a_2, a'_2. This relation means, as will be clear to those versed in the direction finding art, that the direction of the line on the oscillograph screen read against a suitable direction scale will be the direction of the incoming signal.

For the determination of sense the aerial a_3 is brought into operation. This will be, in the case of an Adcock Direction Finder, a vertical conductor placed at the centre of the square formed by the remaining aerials of the system. The signal from the aerial a_3 passes through coupling devices A3 to the modulator M6 in which an action occurs exactly similar to that in M1 and M2 except that the second modulating frequency is 2000 c. p. s. The component of the output from the modulator M6, consisting of a carrier of intermediate frequency together with its two side bands corresponding to 2000 c. p. s., is selected and passed to the common intermediate frequency amplifier I. F. A. The 2000 c. p. s. output from D is selected by the filter F. 2000 and passed through the phase changing network P2 and then to the amplifier G2. The frequency at this point is, of course, that of the oscillator O_2 which is also that of the voltage applied to the plates of the oscillograph. The output from G2 is then injected into the high tension supply circuit of the oscillograph by means of the transformer T. By suitable adjustment of P2 the voltage injected into the high tension circuit can be made to be in phase with that applied to the deflecting plates. Again by design of the network P2, this relationship of phase can be made to remain stable over a band of frequencies. The effect of injecting the voltage in series with the high tension supply is to vary, in a periodic manner, the sensitivity of the oscillograph and in such a way that the portion of the line on the oscillograph screen on one side of the origin, is considerably different in length from that on the other. In this way the sense of the bearing will be clearly indicated and will be arranged for example, to be on the side of the longer portion of the line.

It will be clear from the foregoing that if desired the sense circuit may be left in operation continuously so that the bearing and sense are indicated simultaneously. However, the variation of the high tension voltage apart from changing the sensitivity of the oscillograph and therefore the length of the line, as described, causes also other changes in the characteristics of the oscillograph which affect adversely the accuracy of indicated bearing and the facility of reading it. An alternative and preferred way of carrying out this part of the invention therefore is shown in Fig. 3. The amplifier G2 of Fig. 3 feeds a transformer T_1, the secondary of which is connected to a unilateral conducting device such as a metal rectifier R and resistance r in series. The resistance is also included in series with the feed to the focussing, control or other electrode, E, in the oscillograph. By this arrangement during the half cycle in which the rectifier R is non-conducting, the supply to the electrode being utilized, here assumed to be the focussing electrode, is normal and the oscillograph functions normally with clearly defined focus and so one-half of the line indicating the bearing is traced out. During the next half cycle a current flows through the rectifier R and the potential drop occurring across the resistance r is applied to the focussing electrode in addition to the potential applied from any other source V. It is arranged that the extra potential is of such a value and sign that the spot on the oscillograph screen, in effect, vanishes, so that only one-half of the bearing indicating line is traced, which line now gives both sense and bearing simultaneously, the latter with an accuracy and facility equal to the case of the full line method.

It should be noted that P1 and P2 once having been adjusted will not afterwards require further adjustment even should the oscillators vary somewhat in frequency. The frequency stability of the oscillators obtainable by the simplest and well known means is ample for maintaining this condition.

It will be apparent to those familiar with the

Adcock principle of compounding the signal outputs from the diagonally opposite aerials of the system, that the signals from A_1 and A_2, Fig. 1, may be in phase or in anti-phase according to the direction of the signal. If they are in anti-phase and equal, corresponding to a signal arriving from a direction making an angle of 45° with the direction of one of the diagonals of the aerial system, the carriers at intermediate frequency, emerging from the modulators M1 and M2 (assumed of equal conversion conductance) will cancel out though the side bands corresponding to modulations of 1500 c. p. s. and 2500 c. p. s. will remain. This state will be apparent by no indication on the oscillograph and the current in the diode detector. To restore the carrier a phase reversal is introduced in the output from say M1 by a reversing switch arrangement S1. In order to retain the correct relationship between the phases of the voltages arriving on the plates of the oscillograph this phase reversal of the output from M1 must also be accompanied by a similar phase reversal by a switch S2 in the 1500 c. p. s. modulation supply entering M1 (or elsewhere in the low frequency arm of the circuit corresponding to the aerial input A1.)

When the sense aerial a_3 is brought into operation similar steps will have to be taken regarding the phase of the carrier emerging from modulator M6 and the 2000 c. p. s. modulation entering the latter.

The need for operating one or both of the reversing switches S1, S2 involved will be indicated simply by there being little or no indication on the oscillograph.

An alternative method is to make M1 and M2 balanced modulators so that the carrier is eliminated from their output. The carrier is then supplied from the aerial a_3, via modulator M6. For the determination of the bearing the 2000 c. p. s. modulation from oscillator O_2 is cut off from M6. For the determination of sense the modulation is switched on. The operation of the remainder of the circuit is as previously described.

It should be noted that throughout the preceding description the input from a_3 is understood to have a 90° phase shift inserted in the circuit, as will be clear to those familiar with the Adcock type of aerial system.

Fig. 4 shows an alternative arrangement. Here, the modulating frequencies of 1500 c. p. s. and 2500 c. p. s. for supplying modulators M1 and M2 are obtained from oscillators of these frequencies O.1500 and O.2500. Modulator M4 is then supplied by oscillator O.2500 and M5 by oscillator O.1500. The frequency, selected by filters F. 1000, for the deflecting plates of the oscillograph is, in this case, 1000 c. p. s. From modulator M3, 1000 c. p. s. is selected by the filter shown for the modulator M6. The characteristics of the circuit and also its manner of operation are then as in the previous arrangement.

What is claimed is:

1. A radio direction finding system including a plurality of fixed directional aerial systems so positioned with respect to one another that their respective directions of maximum pick-up are at an angle to one another, means to produce under control of the signals from each aerial separate carriers each modulated locally at a different sub-frequency, a common high frequency amplifier on which said carriers are impressed, means associated with the output of said amplifier to select said sub-frequency components, a modulator device to which each of said sub-frequencies are selectively applied associated with each selector means, means for applying oscillations to said modulator devices to produce separate modulation products of the same frequency, an indicating device for giving an indication of the direction of the signal waves incident upon said aerial systems and means for applying said separate modulation products to control said indicator device.

2. A radio direction finding system including a plurality of fixed directional aerial systems so positioned with respect to one another that their respective directions of maximum pick-up are at an angle to one another, a modulator device individual to each aerial, a local beat frequency oscillator common to said modulator devices, separate sources of oscillations of different sub-frequencies; means to impress on each modulator the signals from the associated aerial, the signals from said beat frequency oscillator, and one of said sub-frequency signals, to produce two separate carriers of a common intermediate frequency each modulated in accordance with only one of said sub-frequencies; a common intermediate frequency amplifier upon which said carriers are impressed, means associated with the output of said amplifier to select said sub-frequencies, means for producing separate waves of the same frequency from said sub-frequencies, an indicating device for giving an indication of the direction of the signal waves incident upon said aerials and means for applying said produced separate waves to said indicator.

3. A radio direction finding system including a plurality of fixed directional aerial systems so positioned with respect to one another that their respective directions of maximum pick-up are at an angle to one another, a modulator device individual to each aerial, sources common to said modulators for producing two separate sub-frequency oscillations, means to intermodulate said sub-frequency oscillations to produce other sub-frequency oscillations of respectively different frequencies, means to apply said other oscillations to respective ones of said modulators to produce correspondingly modulated separate carriers, a common high frequency amplifier on which said carriers are impressed, means associated with the output of said amplifier to select said sub-frequency components, a further modulator device for each of said selected components each of said further modulators being supplied with oscillations of the same frequency from said source to produce sub-frequency waves of the same frequency, each having an amplitude proportionate to that of the waves incident on a corresponding aerial, and a device controlled by said same sub-frequency waves for giving an indication of the direction of the signal waves incident upon said aerials.

4. A system according to claim 3 in which said source comprises two oscillator generators of different frequency, and a modulator is provided for intermodulating the waves from said generators to produce respective sum and difference frequencies, means to apply the sum frequency to one of the modulators individual to one aerial, means to apply the difference frequency to the other modulator individual to the other aerial.

5. A direction finding system including a plurality of fixed directional aerial systems so positioned with respect to one another that their respective directions of maximum pick-up are at

an angle to one another, a modulator device individual to each aerial, a pair of separate sub-frequency oscillator sources one for each of said aerials for producing sub-frequency oscillations, means to apply said sub-frequency oscillations to respective ones of said modulators to produce correspondingly modulated high frequency carriers, a common high frequency amplifier on which said carriers are impressed, means associated with the output of said amplifier to select said sub-frequency components, a separte further modulator for each of said components, means to impress oscillations from said sources on corresponding ones of said further modulators to produce separate sub-frequency waves of the same frequency each having an amplitude proportionate to the signals incident on a corresponding one of said aerials, and an indicator device controlled by said separate sub-frequency waves of the same frequency for giving an indication of the direction of the signal waves incident upon said aerials.

6. A radio direction finding system including a plurality of fixed directional aerial systems so positioned with respect to one another that their respective directions of maximum pick-up are at an angle to one another, means to produce under control of the signals from each aerial separate carriers modulated at a different sub-frequency, the last-mentioned means including a pair of local oscillator sources of different sub-frequency, a common high frequency amplifier on which said carriers are increased, means associated with the output of said amplifier to select said sub-frequency components, a device controlled by said selected sub-frequencies for giving an indication of the direction of the signal waves incident upon said aerials, and means are provided for determining the sense of direction of said waves, the last-mentioned means including a non-directional aerial, a third modulator into which said non-directional aerial feeds said third modulator being also fed with local oscillations to produce a third sub-frequency modulated high frequency carrier, means for impressing said third carrier on said common amplifier, means associated with the output of said amplifier to select the sub-frequency component of said third carrier, and means for applying said selected third sub-frequency component to said indicator device to give an indication of the said sense of direction.

7. A system according to claim 6 in which the modulator individual to said non-directional aerial is supplied with oscillations from one of said local oscillation sources.

8. A system according to claim 6 in which means are provided to intermodulate the oscillations from said pair of sources to produce said third sub-frequency.

9. A system according to claim 1 in which a linear detector is provided for rectifying the output of said common amplifier prior to impression of the amplifier output on said selecting means.

10. A system according to claim 1 in which said indicator device is a cathode-ray tube oscillograph, and means are provided for applying the said separate produced waves respectively to the deflecting systems of said oscillograph.

11. A system according to claim 6 in which said indicator is in the form of a cathode-ray oscillograph, and means are provided for translating said third sub-frequency into a corresponding variation of the high tension voltage in the high tension system of the oscillograph to vary correspondingly the sensitivity of the oscillograph as an indication of the sense of direction of the waves incident on the aerial.

12. A system according to claim 1 in which phase changing networks are connected between the output of said amplifier and said indicator device, said networks being adjusted to bring the selected sub-frequency waves into phase alignment.

13. A system according to claim 6 in which said indicator device comprises a cathode-ray oscillograph having a beam focussing system, and there are provided a rectifier for rectifying the selected sub-frequency component of said third carrier and means for applying said rectified component to extinguish the cathode-ray spot during each half cycle.

14. A system according to claim 6 in which an amplifier is provided for amplifying the selected sub-frequency component of said third carrier and said indicator device comprises a cathode-ray oscillograph having means to control the side of the cathode-ray spot, the last-mentioned means including a transformer connected in the output of said sub-frequency amplifier, a uni-lateral conducting device and resistance in series with the secondary of said transformer, and a connection from said resistance to the focussing control electrode system of said oscillograph.

CHARLES FREDERICK
ALLEN WAGSTAFFE.