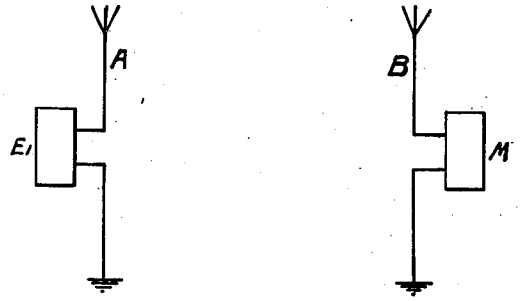
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PROCESS FOR RADIO DIRECTION, LOCATING OBSERVATION, AND THE LIKE

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Fig. 1



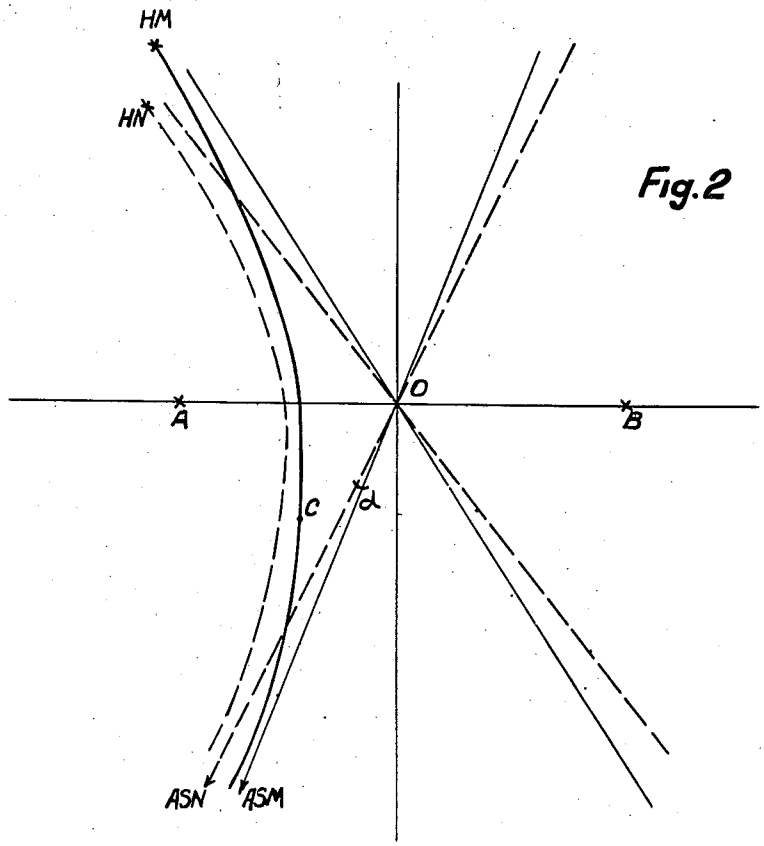


Fig. 2

INVENTOR
F. L. E. Jacquemin
By Robert Robb
Attorneys

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Fig. 3.



Fig. 4.



Fig. 5.

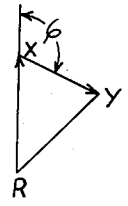


Fig. 6.

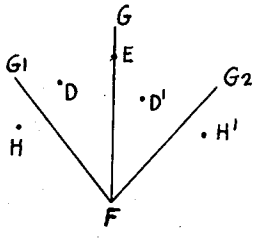
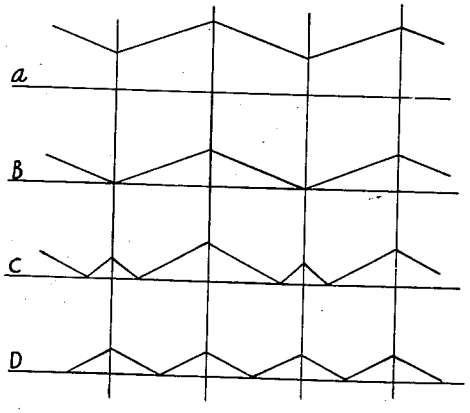


Fig. 7.



INVENTOR
F. L. E. Jacquemin
BY
Martin T. Fisher
ATTORNEY

Patented July 25, 1933

1,919,556

UNITED STATES PATENT OFFICE

FRANCOIS LOUIS EDOUARD JACQUEMIN, OF PARIS, FRANCE, ASSIGNOR TO SOCIETE ANONYME DES ONDES DIRIGEES

PROCESS FOR RADIO DIRECTION, LOCATING OBSERVATION, AND THE LIKE

Application filed April 22, 1927, Serial No. 185,883, and in France May 21, 1926. Renewed June 1, 1932.

This invention relates to means for generating by the aid of two or more radio transmitters an interference observation field between radio waves which are of the same wave length but are out of phase.

An object of the invention is to guide an aeroplane or other moving object equipped with a radio receiver along a fixed path through observation of the interference of radio waves transmitted from two distant antennæ. One antenna transmits an unmodulated wave having a constant length, the other antenna transmits a modulated wave having the same constant wave length. The radio observer in the aeroplane through observation of the interfering waves reaching him is enabled to maintain his position along the fixed path.

In order that the invention may more readily be understood, the principle thereof will now be explained with reference to the drawing. Figure 1 of the drawing shows the two transmitters which set up an interfering field. Figure 2 shows the lines of interference of the field from the transmitters shown by Figure 1. Figures 3, 4 and 5 are vector diagrams showing the field relation of the radio waves emitted by the two stations and received at a given point in the field. Figure 6 shows the field covered by the sweeping of a nodal axis. Figure 7 shows the signals received at stations near and within the zone swept by the nodal axis.

Let it be supposed that there is a radiating system A provided with an emitting station E_1 for sustained waves which emits radio waves (primary waves) and that in the field of the antenna there is a second aerial B emitting radio waves of the same frequency (secondary waves) out of phase to a constant degree with respect to the primary waves.

The second aerial need not be provided with its own source of energy and the secondary waves may only be primary waves reflected by the aerial B; or again, the aerial B may be fed from the emission of station E_1, either with or without the insertion of an emplifier or phase changing device.

If the secondary emission be modulated by any system M, (for example, by breaking the circuit of the aerial B periodically, or varying its wave length, or by varying its resistance) the following phenomena, due to the interference between the modulated and non-modulated fields will be observed.

1. The intensity of reception of the modulated emission at any point C (Figure 2) depends on the phase displacement prevailing at such point C between the primary waves and secondary waves. This phase displacement is a function of several parameters and especially of the difference CA−CB (CA minus CB) of the distances of C from the primary and secondary aerials.

For certain values of such difference, the intensity of reception becomes nil; for others it becomes maximum. When CA−CB varies an amount equal to a quarter of the wave length of the waves emitted, the intensity of reception passes from maximum to zero.

Suppose now for example that the transmitter aerial A (see Figure 1) sends forth an unmodulated carrier wave of a certain frequency and the transmitter aerial B sends forth a carrier wave having the same frequency but modulated. Referring now to Figures 3, 4 and 5, the fields produced at C (Figure 2) by the emissions from A and B are represented one by a vector RX of a constant amplitude and the other by the vector XY of an amplitude periodically variable between the values XY and zero, if the wave emitted at B be totally modulated. The resulting field varies thus periodically between the values RX and RY. In a radio receiver at C (Figure 2) the periodical variation of the field between these two values produces a sound having the frequency of the modulation at B. No sound is heard when the values of the vectors RX and RY are equal. The sound is a maximum when the difference between RX and RY is equal to XY. Figure 3 shows the resultant field when the angle of the dephasage φ is equal to zero. Figure 4 shows the resultant field when the angle of the dephasage φ is equal to 180°. In

both cases whether the angle φ is equal to zero or to 180° the amplitude variation of the resultant field is equal to XY and the sound has maximum intensity. Figure 5 shows the conditions when the vectors RX and RY are equal and no sound is heard at the receiver. The points at which the signals are not heard fall upon lines which are called the "nodal lines of the field" and the points at which the signals are heard with maximum intensity fall upon lines which are called the "ventral lines of the field". These nodal and ventral lines are represented by Figure 2 as the hyperbolic lines HM and HN. The lines along which interfering waves from two similar emitters, such as the two prongs of a tuning fork, arrive to cause wave interference were first proved to be hyperbolic curves by the Weber Brothers (see page 273 of "On Sound" by John Tyndall published by Longmans, Green & Company, London 1867). In the Weber experiments identical non-modulated waves created lines of interference in their field. In the invention herein disclosed, the waves from one station are modulated and the waves from the other station are non-modulated. With this arrangement zeros of sound are obtained at a receiver even though the field strength of the secondary station may be considerably less than that of the primary station.

2. The zero strength hyperbola HN and the maximum strength hyperbola HM and their asymptotes ASN and ASM with which they substantially coincide when the distance CA is sufficiently large are thus easily observable and allow certain directions to be marked The angular separation α of two consecutive zero and maximum asymptotes ASN and ASM may, moreover, be adjusted to a selected value for example by varying the length of wave emitted.

The marking may, moreover, be improved in many ways, for example:

(a) By employing in place of a single aerial B two or more combined aerials whose modulations may be of the same or different frequencies, and displaced in or out of phase by a definite amount with one another.

(b) By employing an emission of periodically varying wave length which effectively periodically displaces all the nodal and ventral lines from their initial position.

(c) By varying the phase of the waves of the secondary aerial or aerials. This variation of phase may be accomplished, for example, by varying the actual wave length of the secondary aerial or by modifying the transmission line from A to B in the case where the oscillations of B are controlled by those of A over such a line.

Suppose now that the phase of the waves from the secondary aerial B is periodically varied, while the waves from the aerial A remain constant. Then, at any point C, the angle of dephasage φ is the sum of two angles. First, the out-of-phase angle α between the primary and secondary currents the variation of which is due to the periodical variation of the phase of the secondary currents, and second, the angle β, which depends only upon the difference CA−CB and has the same value at all points where CA−CB has the same value, that is on the hyperbolæ such as HM and HN (Figure 2). The locations where the dephasage angle φ has constant values at a definite time is thus made up of one or more hyperbolæ, the number of such hyperbolæ being the greater as the distance AB is large with respect to the length of the wave emitted. These nodal and ventral hyperbolæ periodically oscillate to both sides of their mid-position when the angle α is periodically varied.

In particular in the case of the single secondary, if the phase of the waves from such variable aerial is rendered variable in accordance with a determined law, the zero and maximum lines of the interference field will oscillate from side to side of their mid-position according to the same law. At any point of the field, the receiver, therefore, will not detect a consistent sound but a sound of variable amplitude passing or not through zero according as this point is or is not in the zone swept by the zero line ASN. Outside this zone there will be a maximum and a zero period. In this zone there will be two maxima and two minima per period and the maxima which will follow two consecutive minima will possess greater difference of amplitude as the point is set further and further from the mid-nodal line. It is only when the point of observation is upon the mid-position of this line that the maxima will be of equal amplitude. The equality may therefore serve and suffice to define the direction of the zero line of the interference field.

It is desirable that the law of variation of phase is such that the passages of the oscillating nodal line become separated by two equal periods of time; for example, a law such that the angular speed of the displacement of the nodal line remains constant, or one that may be represented by a symmetrical graph such as a sine wave may be selected. The sensation of isochronism obtained in the axis will define this axis with precision.

This phenomena can be more easily understood with reference to Figures 6 and 7. The nodal line FG sweeps the zone in the sector FG_1—FG_2. At a point H near FG_1 exterior the swept zone, the intensity of reception will lessen without becoming null when FG approaches FG_1, and will increase when FG moves toward FG_2. This is rep-

resented by curve *a* of Figure 7. When H arrives on FG, the course of the curve remains the same, but the minima are void as shown by curve *b* of Figure 7. In the interior of the swept zone at point D, the intensity of the reception becomes zero twice at periods of unequal time. This is shown by curve *c* of Figure 7. Finally at E at the mid-point of the nodal axis FG the intensity becomes zero twice a period at equal intervals of time, as shown by curve *d* of Figure 7. The intensity of the signals received is almost constant when the receiver is far from the swept zone and undergoes a periodical weakening more and more clearly indicated as it approaches the zone. When the zone is entered, there is a halving of the minimum periods, the two minima being very near at first and becoming equidistant when the receiver arrives on the mid-position of the nodal axis.

(*d*) By the variation of the characteristics of the secondary waves and in particular the modulation note so as to allow the two zones situated along the mid-nodal line to be differentiated.

As an example, if the modulation note of the secondary antenna be so varied that with phase displacement in front of the mid-phase, there corresponds a note N_1, and with phase displacement lag there corresponds a note N_2, the consecutive maxima will alternately be of the note N_1 then of the note N_2. On one side of the mid minimum line the note N_1 will be predominant, on the other side the note N_2 will be predominant, the listener, therefore, will be able to tell on which side of the line he is. All the combinations based upon these principles of the variation of one or more characteristics of the secondary emission in connection with the variation of phase will be considered as coming within the scope of the present invention.

Of course, what has been set out for an acoustic note may be repeated for optical, mechanical, or telemechanical phenomena.

The number of lines of zero intensity depend on the relation of the wave length of the emitting waves to the distance between the two antennæ. The larger this relation is, the fewer nodal lines there are and the more widely separated they are. The wave length is chosen to be such that the axes are few and easily identified, and this condition is reached when the length AB is near the length of the wave utilized. The two emitting stations are disposed on each side of the fixed path in such a way that the nodal axis coincides with the fixed path along which it is intended that the airplane shall fly. The chosen nodal axis is made to oscillate periodically to either side of its mid-position, and, in so oscillating, it sweeps over a comparatively narrow zone. The airplane crossing this zone will notice the intensity of the signal becoming zero at first, once at intervals of time equal to the period of sweeping, then twice a period at unequal intervals, and, finally, when it is at the mid-position of the nodal axis, the signal will become maximum and zero at equal intervals of time. A modification of the modulation frequency to give the distinctive notes N_1 and N_2 described above concomitant with the phase variation enables it to be known at the airplane on which side of the mid-nodal line the airplane is traveling. It is thus possible to guide the airplane over the fixed path by observation of the signals heard.

If reception takes place at A or very near to A with respect to the distance AB, the intensity of reception will vary with the distance AB. It will pass through the maxima and minima every time the distance AB varies a one-quarter of the wave length of the wave emitted at A. By counting the number of maxima and minima in a predetermined time, the speed of movement of B with respect to A (approaching or receding), will be known.

If the emission at A is directive bearings can be ascertained at the same time.

This measure is also possible even if the aerial B is not modulated. In this case it will be sufficient to arrange for example, in the neighborhood of the primary emission a modulated aerial tuned to the wave length of emission and so arranged that unless there be another aerial in the field, its modulation is not perceptible. This allows one to note at A any body which can act as a secondary antenna without it being necessary for such body to participate in the observation and, therefore, without the necessity for an observer thereat knowing that such observation is being made (ships, aeroplanes, etc.).

In place of using an auxiliary modulated antenna it is possible to perceive waves reflected by a non-modulated aerial either by heterodyning at reception or by employing as emitter a group of two aerials (loops, for example) the resultant strength of reception at the receiver being rendered perceptible by modulation of the output of one of the aerials, the arrangement being such that this resultant strength of reception is zero unless a non-modulated aerial be present. The distance AB may further be measured by observing the difference or variation in wave length required to give two successive maxima of reception when the length of emission is varied.

Finally an appreciation of the distance AB may be obtained from a knowledge of the displacement of the nodal and ventral lines as above explained. With these indication and for a given station it is possible to draw up in advance a true hertzian chart

which allows to be noted the position in direction, distance, speed and direction of movement of objects adapted to act as secondary vibrators.

All this requires the operation only of the primary emitter under control. The secondary vibrator has no active role and an observer there is unaware of the observation to which he is subjected. This is a process of locating upon the ground fixed or moving objects, of geodetic points, nautical or aerial navigating bodies etc.

When referring to the changing or varying of the phase relation in the claims, it is to be understood that any method (such as periodically breaking one of the circuits or varying its wave length or its resistance) which will have the result of changing the interference pattern, is to be included within such phase.

I claim:

1. The method of determining the position of an object which comprises emitting sustained radio waves of the same wave length from two spaced points, and modulating radio waves emitted from only one of said points to form a special interference pattern having at least one nodal axis.

2. The method of determining the position of an object which comprises emitting sustained radio waves of the same wave length from two spaced points, modulating radio waves emitted from only one of said points to form a special interference pattern having at least one nodal axis, and changing the phase relation of said waves between predetermined limits to sweep said axis across a predetermined field.

3. The method of determining the position of an object which comprises emitting sustained radio waves of the same wave length from two spaced points, modulating radio waves emitted from only one of said points to form a special interference pattern having at least one nodal axis, changing the phase relation of said waves between predetermined limits to sweep said axis across a predetermined field, and modifying by a certain amount for a definite time the frequency of modulation of the modulated radio waves emitted from said one point to differentiate the two sides of the field from one another.

4. The method of determining the position of an object which comprises emitting radio waves of the same wave length from two spaced points to form an interference pattern having a nodal axis, changing the phase relation of the said waves between predetermined limits to sweep said axis across a predetermined field, and impressing a distinctive modulated note on the waves emitted from one of said points to indicate the position of said object relative to a predetermined position of said axis.

5. The method of determining the position of an object which comprises emitting radio waves of the same wave length from two spaced points to form an interference pattern having a nodal axis, changing the phase relation of said waves between predetermined limits to sweep said axis across said field, and impressing distinctive contrasting modulated notes on the waves emitted from one of said points to indicate the position of said object relative to a predetermined position of said axis.

6. The method of determining the position of an object which comprises emitting from two spaced points radio waves of the same wave length to form an interference pattern having a nodal axis, the mid-position of which corresponds to the mean difference of phase of the emitted waves, changing the phase relation of said waves to sweep said axis across said object, and impressing a distinctive modulated note on the waves emitted from one of said points to indicate the position of said object relative to the mid-position of said axis.

7. The method of determining the position of an object which comprises emitting from two spaced points radio waves of the same wave length to form an interference pattern having a nodal axis, the mid-position of which corresponds to the mean difference of phase of the emitted waves, changing the phase relation of said waves to sweep said axis across said object, and impressing distinctive contrasting modulated notes on the waves emitted from one of said points to indicate the position of said object relative to the mid-position of said axis, the waves emitted from the other point being unmodulated.

8. The method of guiding a moving object along a fixed path which comprises emitting on each side of said path radio waves of the same wave length and forming an interference pattern having a nodal axis along said path, the mid-position of which axis corresponds to the mean difference of phase of the emitted waves, changing the phase relation of said waves to sweep said axis across said path and said object, and impressing a distinctive modulated note on the waves emitted from one side of said path to indicate the position of said object relative to the position of said axis.

9. The method of guiding a moving object along a fixed path which comprises emitting on each side of said path radio waves of the same wave length to form an interference pattern having a nodal axis along said path, the mid-position of which axis corresponds to the mean difference of phase of the emitted waves, changing the phase relation of said waves to sweep said axis across said path and said object, and impressing distinctive contrasting modulat-

ed notes on the waves emitted from only one side of said path to indicate the position of said object relative to the mid-position of said axis, the waves emitted from the other side of the path being unmodulated.

10. The method of determining the position of an object which comprises emitting from two spaced points radio waves of the same wave length to form an interference pattern having a nodal axis the mid-position of which axis corresponds to the mean difference of phase of the emitted waves, and changing the phase relation of said waves to sweep said axis across said object from one side to the other of the mid-position of said axis to indicate the position of the said object relative to the mid-position of said axis.

In testimony whereof, I have signed my name to this specification this 13th day of May 1932.

FRANCOIS LOUIS EDOUARD JACQUEMIN.