

July 9, 1946.

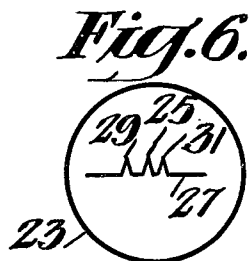
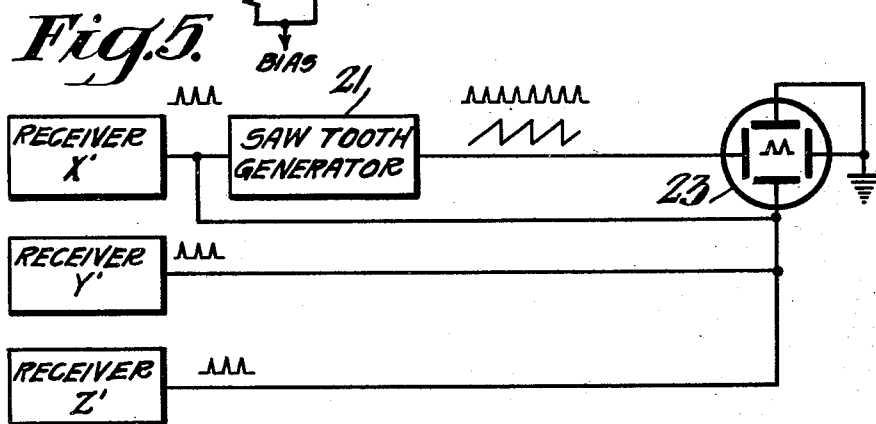
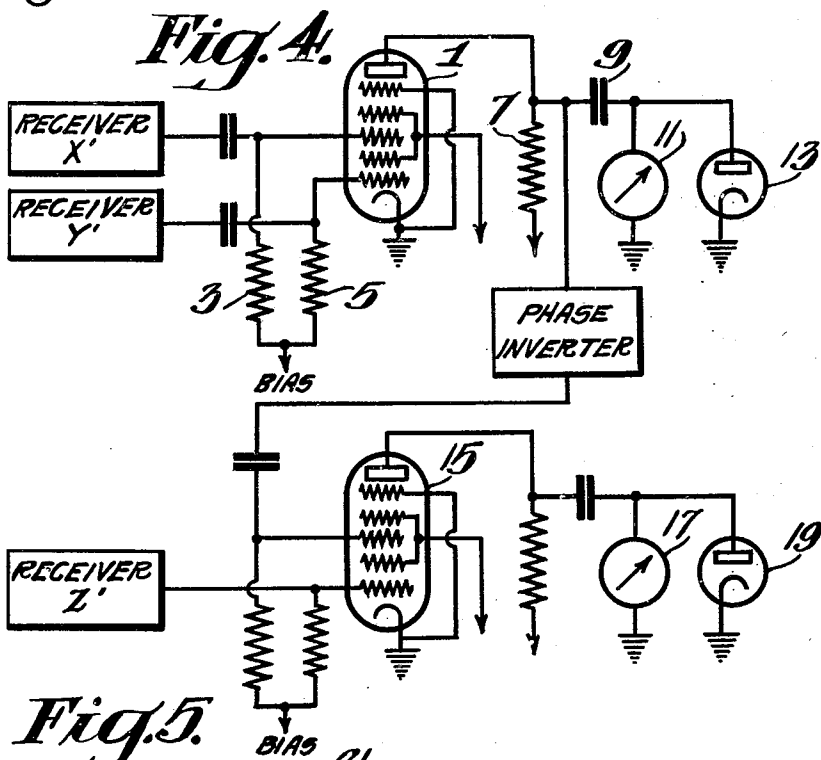
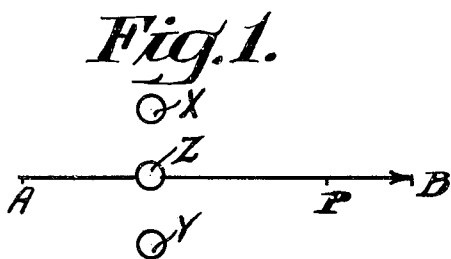
E. I. ANDERSON

2,403,429

RADIO BEACON SYSTEM

Filed Nov. 2, 1942

3 Sheets-Sheet 1



Inventor
Earl I. Anderson
C. D. Quake
 Attorney

July 9, 1946.

E. I. ANDERSON

2,403,429

RADIO BEACON SYSTEM

Filed Nov. 2, 1942

3 Sheets-Sheet 2

Fig. 8.

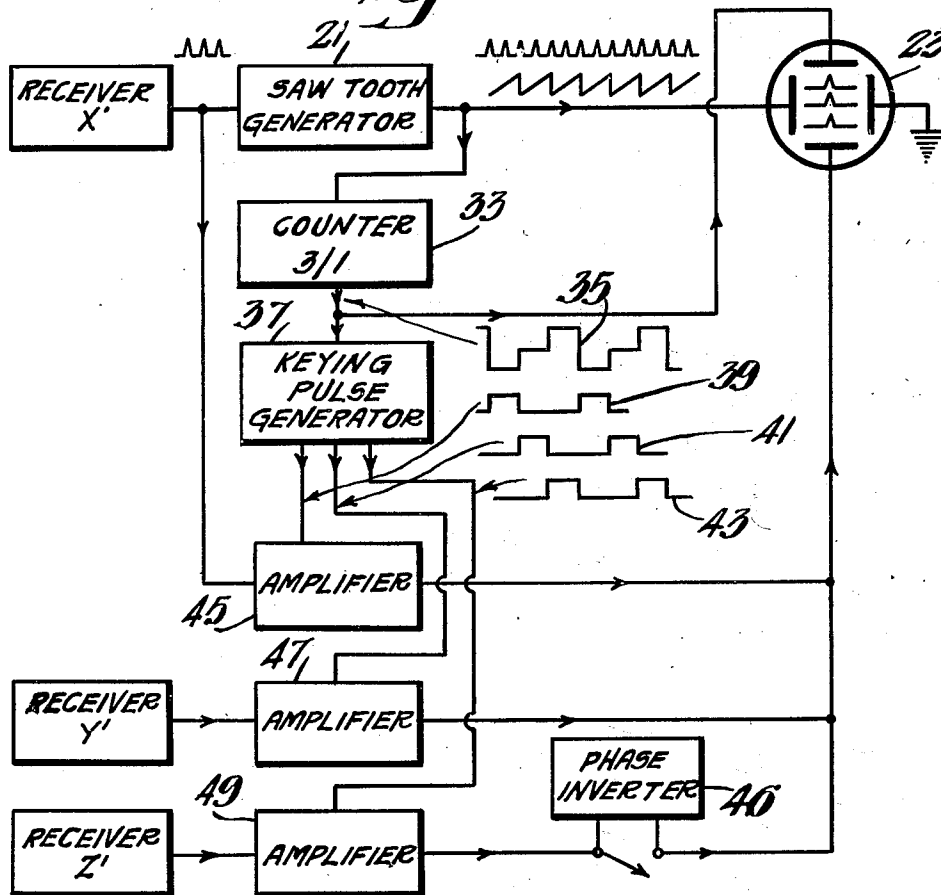


Fig. 9.



Fig. 10.



Fig. 11.



Fig. 8a.

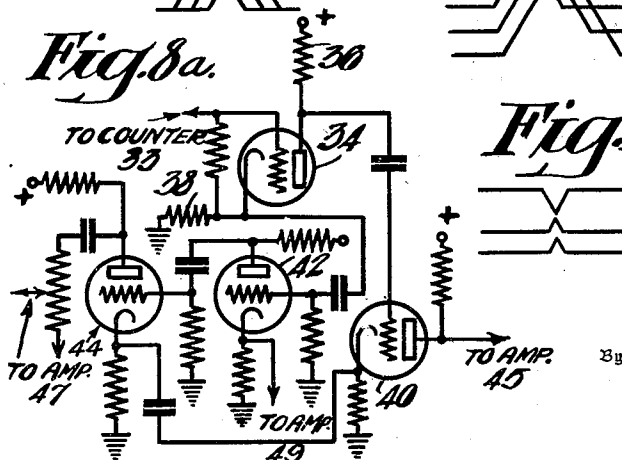


Fig. 12.



Inventor
Earl I. Anderson

C. D. Inaba

Attorney

UNITED STATES PATENT OFFICE

2,403,429

RADIO BEACON SYSTEM

Earl I. Anderson, Manhasset, N. Y., assignor to
Radio Corporation of America, a corporation of
Delaware

Application November 2, 1942, Serial No. 464,294

7 Claims. (Cl. 250-11)

1

This invention relates to a course and position determining system employing radio beacons, and receiving apparatus carried by a mobile craft or vehicle whose position is to be ascertained.

Radiogoniometric systems, in which bearings of two or more fixed stations with respect to a craft are used to determine its position by triangulation, are subject to various well known sources of error. Under certain conditions of abnormal wave polarization and high noise level such systems are useless. These difficulties often occur at a time when it is impossible to obtain a fix by astronomical or other means and dependable radio location is most required.

It is proposed to use two or more fixed transmitters sending timed impulses to determine the relative time required for a pulse from each of the transmitters to travel between the fixed stations and the position to be determined. Since the velocity of propagation of radio waves is invariable, the time is in each case an accurate measure of the distance. Although reflections and deviations of the wave may occur, as long as any component of the radio energy travels over the direct path, it will arrive first at the receiver. The position may be ascertained in terms of the relative time of arrival of pulses from the fixed stations.

It is an object of this invention to provide an improved method of and means for determining position.

Another object is to provide a system for ascertaining the position of a receiver station in terms of the times of arrival of pulses transmitted from stations of known positions.

A further object is to provide an improved method of and means for indicating automatically the position of a mobile craft with reference to a given course and destination.

Other and incidental objects will become apparent to those skilled in the art upon consideration of the following description, with reference to the accompanying drawings, of which Fig. 1 represents the course and destination of an airplane, for example, with reference to fixed ground stations.

Figs. 2 and 3 illustrate pulses received from the ground stations at a receiver on the airplane.

Fig. 4 is a schematic circuit diagram of a system for providing indication of the position of a receiver with respect to three transmitters.

Fig. 5 is a schematic diagram of a modified indicator system.

Figs. 6 and 7 illustrate typical indications provided by the system of Fig. 5.

2

Figs. 8 and 8-A show a modification of the system of Fig. 5.

Figs. 9, 10, 11 and 12 show various types of indications which may be produced by the system of Fig. 8.

Fig. 13 illustrates another modification of the system of Fig. 5; and

Figs. 14, 15, 16, 17 and 18 show typical indications obtained with the system of Fig. 13.

Referring to Fig. 1, assume that transmitters are located at X and Y, and it is desired to follow a course along the line AB, perpendicular to and bisecting the line between the transmitters X and Y. Discrete pulses of high frequency energy are periodically emitted simultaneously by transmitters X and Y. These pulses are transmitted on different frequencies and picked up by separate receivers at the mobile station. The outputs of the two receivers are applied to a multigrid tube arranged to produce output current only when the input pulses coincide. This output current is applied to a peak indicating device.

As long as the mobile station follows the course AB the arrival of the pulses from the two stations will coincide, producing an output pulse like that shown in Fig. 2. When the mobile station is off the course AB, the output pulse will decrease in amplitude, reaching zero when the difference in time of arrival exceeds the duration time of one pulse. This is illustrated in Fig. 3.

In order to indicate the arrival at a destination, a third transmitter Z, may be provided anywhere along the course AB and arranged to send out pulses like those from X and Y, but with a slight delay, so that when all three pulses coincide at the receivers, the craft is at its destination, indicated by the point P in Fig. 1.

Referring to Fig. 4, an indicator system is shown, comprising receivers X', Y', and Z' arranged to respond to transmitters X, Y and Z respectively. Receivers X and Y are connected to two control grids of a multigrid tube 1. The control grids are both normally biased to cut off by means of a voltage from a D. C. source (not shown) applied between the cathode of the tube 1 and the grid leaks 3 and 5.

The plate circuit of the tube 1 includes a load resistor 7 coupled through a blocking condenser 8 to a peak indicator comprising a meter 11 shunted by a rectifier 13.

A second multigrid tube 15, biased like the tube 1, has one control grid connected through a phase inverter 14 to the plate circuit of the tube 1 and the other connected to the receiver Z'. A

peak indicator including a meter 17 and rectifier 19 is connected to the plate circuit of the tube 15.

In operation, the plate current pulses of the tube 1 are directly related in magnitude to the time of overlapping of the pulses received by the receivers X' and Y'. Thus the meter 11 will show a maximum deflection when the craft is on course, and a decrease upon departure from the course. Similarly the deflection of the meter 17 will increase as the destination is approached, attaining a maximum value when it is reached and dropping off again if it is passed.

Fig. 5 shows a system for producing course and destination indications on the screen of a cathode ray tube. A saw-tooth generator 21, which may be a blocking oscillator, for example, of the type described in U. S. Pat. 2,101,520 to Tolson et al., is synchronized with alternate pulses in the output of the receiver X'. The output of the generator 21 is applied to the horizontal deflection circuit of a cathode ray tube 23, and the outputs of the three receivers X', Y', and Z' are applied together to the vertical deflection circuit of the cathode ray tube.

Alternate pulses in the output of the receiver X' will produce a deflection 25 at the center of the cathode ray trace 27 (Fig. 6). The pulses from receivers X' and Z' will produce deflections 29 and 31 which are displaced from the center as functions of time. When the deflection caused by the receiver Y' coincides with the central deflection 25, the receiver station is on course. When all three deflections coincide, the destination has been reached. In this application the shape of the pulses is not critical except that they should be as short as possible for maximum accuracy. Fig. 7 shows a portion of the trace on the cathode ray tube when the receiver station is slightly off course and near the destination. There is no easy way to distinguish which deflection corresponds to the course indication and which to the destination indication. This information must be determined by going first one way and then the other, long enough to move the deflections a perceptible distance along the trace. If all three pulses arrive at the same time it is impossible to tell if one, two, or three pulses are present, even if the amplitudes are different, since only one composite pulse results.

Fig. 8 shows a system for displaying the received pulses during separate scans of the cathode ray beam, retaining the form of each pulse, even though they arrive coincidentally. The receiver X' synchronizes a saw-tooth generator 21 on alternate pulses, as in the system of Fig. 5. The oscillator output goes to the horizontal deflection circuit of the cathode ray tube 23, and also to a counter circuit 33, which may be of the type described in British Pat. 471,731, of Dec. 4, 1935, to E. L. C. White adjusted for 3 to 1 frequency division to produce the stepped wave 35. The counter output is applied to one side of the vertical deflection circuit of the cathode ray tube 23 and to a keying pulse generator 37. The keying pulse generator provides three square wave outputs, 39, 41 and 43, each corresponding in time with one of the steps of the wave 35. These outputs are applied to key the amplifiers 45, 47 and 49 respectively. The circuit of the keying pulse generator 37 is shown in Fig. 8A. The stepped wave output of the counter 33 is applied to the grid circuit of a tube 34. The tube 34 is provided with load resistors 36 and 38 in its plate and cathode circuits respectively. The plate circuit is coupled to the grid of a tube

40, and the cathode is coupled to the grid of another tube 42. The plate of the tube 42 is coupled to the grid of a tube 44, and the cathode of the tube 40 is coupled to the cathode of the tube 44.

The tube 34 provides a duplicate of the wave 35 (Fig. 8) in its cathode circuit, and a similar but inverted wave in its plate circuit. The tubes 40 and 42 are arranged to operate as peak amplifiers, "clipping" the highest step of the stepped wave in each case. Thus the output at the cathode of the tube 40 is the wave 43 of Fig. 8 and that at the cathode of the tube 42 is the wave 39. The outputs at the plates of these tubes are similar to, but inverted with respect to the cathode outputs. The wave 41 is provided by applying both of the waves 39 and 43 to the tube 44 so as to provide cutoff bias. Thus the tube will conduct when both voltages 39 and 43 are off.

The amplifiers 45, 47 and 49 may comprise multigrid tubes and circuits like those shown in Fig. 4, or may be any other type of amplifier arranged to be normally cut off and made operative by arrival of a keying impulse. Receivers X, Y' and Z' are connected to the inputs of amplifiers 45, 47 and 49 respectively. The amplifier outputs are applied to the vertical deflecting circuit of the tube 23.

The operation of the system is as follows: Each alternate pulse from the receiver X' causes the cathode ray to trace one horizontal sweep, with its center coinciding in time with the intermediate pulse from receiver X'. The counter 33 is operated by each saw-tooth wave, so that each step in its output has a duration equal to twice the pulse repetition time. The keying pulse generator 37 produces a square wave at each of its output circuits corresponding in time to one level of the stepped wave 35. Thus the amplifiers 45, 47 and 49 are sequentially keyed to operate successively, each for a period equal to twice the pulse repetition time. The wave 35 may be applied to the vertical deflection circuit, as shown, to cause successive horizontal traces to appear at different levels. During successive traces the impulses from receivers X', Y' and Z' are successively indicated on the screen, resulting in an indication like that shown in Fig. 10. If the voltage 35 is not used, the patterns will be like that shown in Fig. 9, or if the outputs of the different channels are unequal, like Fig. 11. An indication like that shown in Fig. 12 may be obtained by reversing the polarity of one of the amplifier outputs, by means of a phase inverter stage 46, for example. The two lower pulses may be used to indicate course and the upper pulse used to show the destination.

Fig. 13 shows a system for providing indications like those shown in Figs. 14, 15, 16, 17 and 18, which can be more readily interpreted than those given by the above described systems. Fig. 14 shows the indication when the craft is on course. Figs. 15 and 16 are off-course indications, to the right and to the left respectively. Fig. 17 indicates the mobile station is on course and near its destination. Fig. 18 is the indication of arrival at the destination. Thus the image on the cathode ray screen simulates a map showing the positions of the craft and its destination, and the course to be followed.

The indicator system (Fig. 13) comprises a saw-tooth wave generator 21 synchronized on alternate pulses in the output of the receiver X', as in the systems of Figs. 5 and 8. A pair of keying

amplifiers 53 and 55, which may be multigrid tubes biased like the tubes 1 and 15 of Fig. 4, are each connected to produce output only when signals are applied to both control grids. The output of the saw-tooth generator 21 is applied to corresponding control circuits of the amplifiers 53 and 55 and to a two to one counter circuit 33. The output of the counter 33 is applied directly to the other of the control inputs of the amplifier 53 and through a phase inverter 51 to the corresponding circuit of the amplifier 55. The output circuits of the amplifiers 53 and 55 are connected to the vertical and horizontal deflection circuits respectively of a cathode ray tube 23. The output of the counter 33 is also connected through a phase inverter 59 to the vertical deflection circuit of the tube 23, and the output of the phase inverter 51 is similarly connected through a phase inverter 57 to the horizontal deflection circuit. The receivers Y' and Z' are connected through switches 61 and 63 to the vertical and horizontal deflection circuits respectively of the tube 23. Switches 61 and 63 may also be operated to connect the receiver X' instead of receivers Y' and Z' to the deflection circuits.

The amplifiers 53 and 55 are keyed alternately by the output currents 65 and 67 of the counter 33 and phase inverter 51 respectively to produce alternate horizontal and vertical sweeps of the cathode ray beam of the tube 23. The outputs 69 and 71 of the amplifiers 53 and 55, if applied alone to the respective deflection circuits of the tube 23, would produce alternate vertical and horizontal sweeps from the undeflected spot position, at the approximate center of the screen. The traces would intersect at their ends at this point. The phase inverters 57 and 59 add square wave components derived from the counter output to the outputs 71 and 69 of the keying amplifiers, providing resultant voltages 73 and 75 respectively. This is done to make the vertical and horizontal cathode ray traces cross at their centers by shifting the axis of the sawtooth waves 69 and 71 from zero voltage to one-half the peak voltage.

Alternate pulses in the output of the receiver X' control the initiation of each sweep, which requires a time equal to twice the pulse repetition period. An impulse received on receiver Y' during the horizontal sweep period produces a vertical deflection; if this coincides with an impulse from receiver X', the deflection occurs at the center of the horizontal sweep. A pulse from receiver Z' during the vertical sweep produces a horizontal deflection, above or below the center according to whether it is later or earlier than the pulse from X'. When all three pulses coincide in arrival, the deflections both occur at the intersection of the sweeps.

The switches 61 and 63 are provided so that the output of the receiver X' may be applied to either of the deflection circuits to enable observation of the amount of square wave component added to each of the deflection saw-tooth voltages, for the purpose of adjustment.

Thus the invention has been described as a course and destination indication system for mobile craft. Trains of suitably timed impulses are transmitted at equal repetition periods from a plurality of fixed stations and received at the mobile station. Coincidence of two of the pulse trains at the receiver station occurs when the craft is on course, and coincidence of all three occurs at the destination. Several arrangements for providing visual indications in response to the received pulses are illustrated.

I claim as my invention:

1. A system for indicating a position in response to arrival at said position of pulses transmitted in predetermined time relationship from a plurality of spaced transmitters, comprising receiver means, a cathode ray tube, means for initiating a sweep of the beam of said cathode ray tube in response to the arrival of each alternate pulse from one of the transmitters, and means for deflecting said beam transversely of said sweep in response to the arrival of pulses from each of the other transmitters.

2. A system for indicating position in response to the relative timings of a plurality of trains of periodic impulses comprising a radio receiver arranged to respond to one of said trains, a saw-tooth wave generator controlled by the output of said receiver to operate at a frequency one half of the impulse repetition frequency of said train, other radio receivers arranged to respond respectively to others of said trains, and a cathode ray tube provided with a horizontal deflection circuit connected to said saw-tooth wave generator and a vertical deflection circuit connected to said other receivers.

3. A system for indicating position in response to the relative timings of a plurality of impulse trains comprising a radio receiver arranged to respond to one of said trains, a saw-tooth wave generator controlled by the output of said receiver and arranged to synchronize with alternate impulses of said train, a frequency divider connected to said saw-tooth wave generator and arranged to produce in response thereto a stepped wave, each step thereof corresponding in duration to one cycle of operation of said saw-tooth wave generator, square wave generators arranged to operate selectively in response to the occurrence of respective levels of said stepped wave, other radio receivers arranged to respond respectively to others of said impulse trains, amplifiers connected to the outputs of the receivers and each arranged to be controlled by one of said square wave generators, and a cathode ray tube, with a first deflection circuit connected to said saw-tooth wave generator and a second deflection circuit connected to said frequency divider and to all of said amplifiers.

4. A system for determining position in response to the relative timings of a plurality of impulse trains comprising a plurality of radio receivers, each arranged to respond to one of said trains, a cathode ray tube, means for deflecting the beam of said cathode ray tube in alternate sweeps at right angles to each other, said means being arranged to respond to the output of one of said receivers so that each of said sweeps has a duration of twice the pulse repetition period of said output, and means for deforming each of said sweeps in response to impulses in the output of a corresponding one of the others of said receivers.

5. A system for indicating a position in response to the relative timings of a plurality of trains of periodic impulses comprising a radio receiver arranged to respond to one of said trains, a saw-tooth wave generator connected to said receiver and arranged to initiate a cycle in response to the arrival of each alternate impulse of said train at receiver, a cathode ray tube with one deflection circuit connected to said saw-tooth wave generator whereby the beam of said cathode ray tube produces a linear trace on the screen thereof, other radio receivers arranged to respond respectively to others of said trains, and con-

7

nections from the output circuits of all of said other receivers and another deflection circuit of said cathode ray tube whereby said linear trace is deformed at points along its length related in their positions to the relative timing of said impulse trains.

6. The method of indicating on a cathode ray tube the position of a station in response to arrival at said station of a plurality of trains of timed pulses, comprising the steps of initiating a sweep of the beam of said cathode ray tube in response to the arrival of each alternate pulse of one of said pulse trains, and deflecting said

8

beam transversely of said sweep in response to the arrival of the pulses of each of the other of said pulse trains.

7. The method of indicating position on a cathode ray tube in response to the relative timings of a plurality of trains comprising the steps of deflecting the beam of said cathode ray tube in alternate sweeps at right angles to each other in response to the successive alternate pulses of one of said trains, and deforming each of said sweeps respectively in response to the pulses of corresponding other trains.

EARL I. ANDERSON.