Jan. 16, 1940. F. POPE 2,187,097

RADIO BEACON SYSTEM

Filed June 12, 1937

Fig. 1

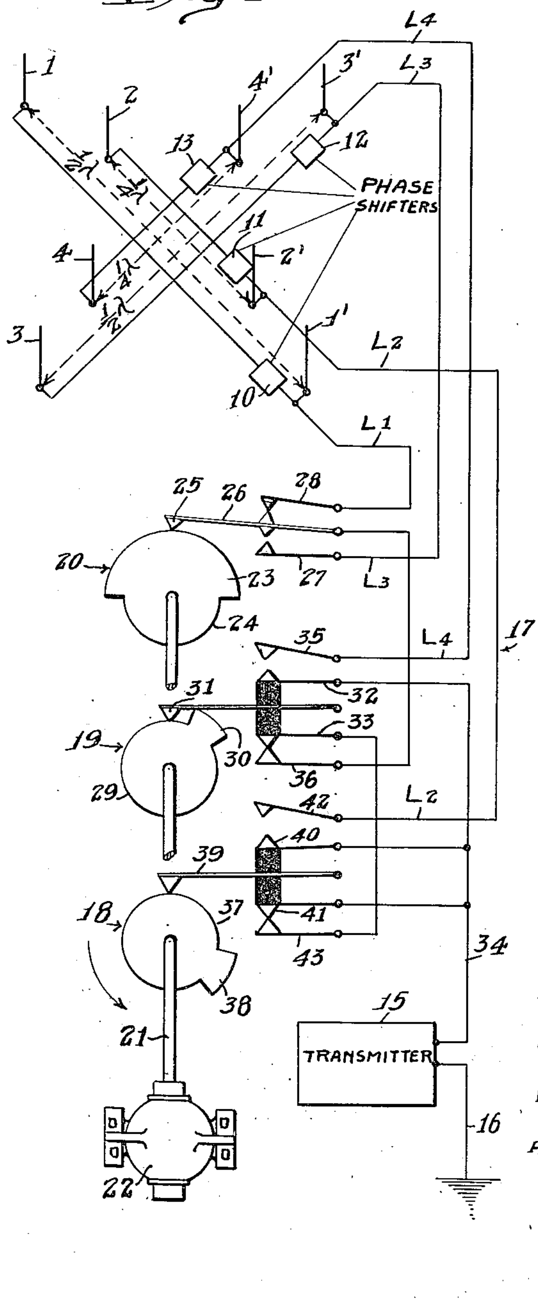


Fig. 2

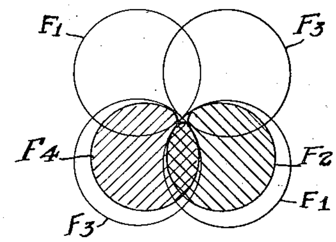


Fig. 3

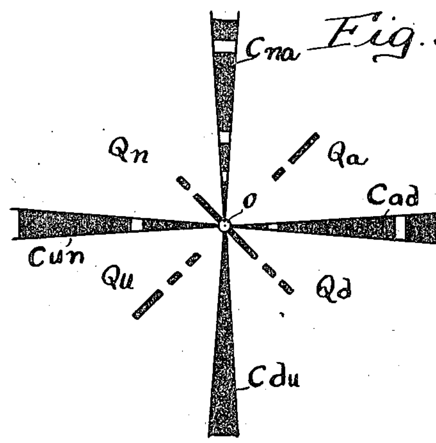
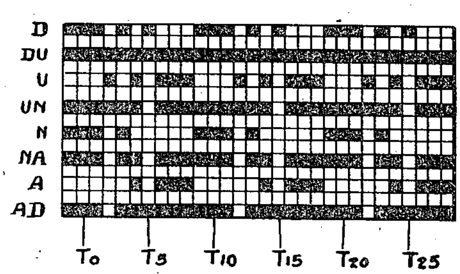


Fig. 4



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RADIO BEACON SYSTEM

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6 Claims. (Cl. 250—11)

This invention relates to radio signal transmitting systems for transmitting signals in different directions for guiding movable craft, particularly aircraft.

An object of the invention is to provide different code signals in different sectors extending from a beacon point whereby a movable craft receiving such signals can determine from the nature of the signals received its position relative to the beacon point.

Another object is to produce code signals in different sectors extending from a beacon point of such characteristics that the code signals in adjacent sectors will combine to produce "on course" signals of different code characteristics in a plurality of different "on course" positions.

Another object is to provide a simple and effective antenna system and antenna energizing system for producing different code signals in a plurality of different directions extending from the antenna system from a single source of radio frequency energy.

The present invention involves improvements and modifications in the present well-known A and N radio beacon system in quite general use. In the A and N system, an antenna system is employed which transmits radio waves modulated with the telegraph code for the letter A in two opposite quadrants and transmits radio waves modulated with the telegraph code signal for the letter N in the other opposite quadrants. The dots and dashes representing the letter A are transmitted alternately with the dots and dashes representing the letter N so that in the region between each pair of adjacent quadrants where the radio waves, modulated with the dots and dashes representing the letter A overlap the radio waves modulated with the dots and dashes representing the letter N, the signals combine to produce an uninterrupted wave which produces a continuous sound in the receiver of an aircraft, thereby indicating that the craft is on one of four "on course" positions. A serious defect of the A-N system is that a pilot receives the same signals in all four "on course" positions so that he cannot determine from the nature of the signal alone which of the four courses he may be on. Furthermore, since the same code signal is transmitted in each pair of diagonally opposite quadrants, the pilot cannot tell directly from the signal received which of two quadrants he is in.

In accordance with the present invention, I overcome the serious defects described in the A-N system by transmitting entirely different code signals in all four quadrants so that a pilot is immediately apprised by the code signal he receives in which of the four quadrants he is located. Further, in accordance with the invention, I so select and relatively time the code signals transmitted in the four quadrants that the signals in at least several pairs of adjacent quadrants combine to produce different signals on the "on course" positions lying between the adjacent quadrants.

The invention will now be explained by describing in detail one specific embodiment thereof.

In the drawing:

Fig. 1 is a schematic diagram of an antenna array and an antenna energizing circuit that may be employed in practicing my invention.

Fig. 2 is a conventional diagram illustrating the shapes of the fields of radiation produced by the different sets of antennas in Fig. 1.

Fig. 3 is a conventional diagram showing the code signals produced in various directions extending from a beacon, as illustrated in Fig. 1.

Fig. 4 is a diagram showing the relative timing of the signals transmitted in different directions from the beacon illustrated in Fig. 1.

Referring first to Fig. 1, there is disclosed in the upper portion of this figure an antenna array comprising eight different antennas arranged to be simultaneously energized in pairs for the directional transmission of radio signals therefrom. One pair of antennas 1 and 1′, respectively, are positioned one-half wave length apart and are energized from a common feeder line L_1. The feeder line L_1 feeds directly to the antenna 1′ but feeds to the antenna 1 through a phase shifter 10 which shifts the phase of the radio frequency waves applied to antenna 1 180° with respect to the phase of the waves applied to antenna 1′. Antennas 1 and 1′ when energized with radio frequency currents differing in phase by 180°, produce a radiation field of figure eight characteristics as shown by the circles F_1 in Fig. 2, the axis of maximum radiation being along a line interconnecting antennas 1 and 1′.

A second pair of antennas 2 and 2′, positioned in a line parallel to a line interconnecting antennas 1 and 1′ but positioned one-quarter wave length apart, are connected to a second feeder line L_2. In this case antenna 2′ is fed directly from the line L_2 but antenna 2 is fed through a phase shifter 11, which shifts the phase of the current in antenna 2 90° with respect to the phase of the current in antenna 2′. It is well-known that two vertical antennas positioned one-quarter wave length apart and energized with currents differing in phase by 90° produce a field of radiation of cardioid shape in which maximum radiation occurs in one direction and minimum radiation in the opposite direction to the direction of maximum radiation, the directions of maximum and minimum radiation depending upon in which antenna the current is in leading phase relation. The phase shifter 11 is adapted to so control the relative phases of the currents in antennas 2 and 2′ as to produce the maximum radiation in the direction of antenna 2′ as shown by the shaded area F_2 in Fig. 2.

The third pair of antennas 3 and 3′, respectively, are separated one-half wave length apart along a line at right angles to the line interconnecting antennas 1 and 1′ and are energized from a feeder line L_3. The antenna 3 is supplied with current differing in phase by 180° from the current supplied to antenna 3′ by virtue of a phase shifter 12 inserted between the feeder line L_3 and antenna 3. Antennas 3 and 3′, being energized by currents differing in phases by 180°, as described, produce a radiation field of figure-8 outline, as indicated by the circles F_3 in Fig. 2. The direction of maximum radiation is at right angles to the direction of maximum radiation of the fields F_1 and F_2.

The last pair of antennas 4 and 4′ are spaced one-quarter wave length apart in a direction along a line parallel to a line connecting antennas 3 and 3′ and are energized with currents differing in phase by 90° from a feeder line L_4, the line L_4 feeding directly to antenna 4′ and feeding to antenna 4 through a phase shifter 13. The relative phases of the currents in the antennas 4 and 4′ are such as to produce a cardioid field pattern as indicated at F_4 in Fig. 2, having a direction of maximum radiation in a direction looking from antenna 4′ to antenna 4.

The four sets of antennas described are all energized from a common source of radio frequency energy indicated as a transmitter 15. In the purely schematic circuit of Fig. 1, the transmitter 15 is shown connected between ground 16 and the various feeder lines L_1, L_2, L_3, and L_4 through a switching assembly 17. It is to be understood, however, that this particular method of energizing the antennas is adopted for the purpose of simplifying the drawing and that in practice the transmitter 15 might better be connected to the various antennas through transmission lines involving pairs of conductors, the ground connection for each antenna being made closely adjacent that antenna. Furthermore, the system may be employed with antennas functioning without ground connection in accordance with well-known practice in the art. The present invention does not reside in the exact way of energizing the antennas, but rather in the use of antennas of particular radiation characteristics in combination with means for successively energizing different antennas in a particular sequence. The diagram of Fig. 1 fully illustrates the sequence in which the various antennas are energized.

The switching system 17 comprises three separate switches, each controlled by separate cams 18, 19 and 20, respectively, all mounted for simultaneous rotation on a common shaft 21 driven at a uniform speed by any suitable source of power illustrated as a motor 22. Cam 20 has a lobe 23 extending half-way around and a dwell 24 extending the rest of the circumference and has a follower 25 which is connected to a movable contact 26 cooperating with a back contact 27 connected to transmission line L_3 and a front contact 28 connected to transmission line L_1. The cam 19 has a dwell 29 extending almost all the way around it and a short lobe 30, the lobe being oriented as shown with respect to the lobe 23 of cam 20. Cooperating with the cam 19 is a cam follower 31 which is mechanically connected to, but electrically insulated from, a pair of electrical contacts 32 and 33, respectively. Contact 32 is connected to a main conductor 34 extending from the transmitter 15 and cooperates with a front contact 35 connected to the transmission line L_4. Contact 33 cooperates with a back contact 36 connected to contact 26 associated with cam 20.

Cam 18, like cam 19, is provided with a long dwell 37 and a short lobe 38 but the lobe 38 is so oriented with respect to the lobe 30 of cam 19 as to lift the cooperating cam follower 39 substantially later in the cycle of operations than the follower 31 is lifted by lobe 30. Cam follower 39 is mechanically connected to, but electrically insulated from, a pair of contacts 40 and 41, respectively. Contact 40 is connected to the main supply conductor 34 and cooperates with a front contact 42 connected to transmission line L_2. Contact 41 is likewise directly connected to the main supply conductor 34 and cooperates with the back contact 43 which is connected with the contact 33 associated with cam 19.

The lobe 30 on cam 19 and the lobe 38 on cam 18 each extend $\frac{1}{10}$ of the circumference of the cams 19 and 18, respectively, and thereby raise their associated cam followers 31 and 39, respectively, during $\frac{1}{10}$ of a revolution of the shaft 21. The shaft revolves at such a speed that the lobes 30 and 38 maintain their followers 31 and 39, respectively, in elevated position for a period of time required to transmit a radio signal having a duration equivalent to one dot in the Morse code. The lobe 23 on cam 20 extending one-half way around the cam raises the follower 25 for a period five times as long as the followers 31 and 39 are lifted.

With the shaft 21 in the position shown, with the follower 25 elevated and followers 31 and 39 depressed, the main supply conductor 34 from transmitter 15 is connected only to the transmission line L_1, connection being effected through contacts 41, 43, 33, 36, 26 and 28, thereby applying energizing current to antennas 1 and 1′ of such phase relation as to produce the field pattern F_1 in Fig. 2. This condition will maintain while shaft 21 rotates through $\frac{1}{10}$ of a revolution. During rotation of shaft 21 through the next $\frac{1}{10}$ of a revolution lobe 30 lifts cam follower 31 to break connection between the main supply conductor 34 and the conductor L_1 at the contacts 33 and 36 and to connect the conductor 34 through contacts 32 and 35 to the conductor L_4, thereby energizing antennas 4 and 4′ in proper phase relation to produce the field pattern F_4 in Fig. 2 during the time interval represented by one dot in the Morse code.

During the next $\frac{1}{10}$ of a revolution of the shaft 21, follower 31 is again in lowermost position and follower 39 is still in lowermost position, whereas follower 25 is still in upper position, thereby again applying the transmitter output to the conductor L_1 and the antennas 1 and 1′ to again produce the field pattern F_1 in Fig. 2 for the interval of one dot. During the next $\frac{1}{10}$ revolution all three followers 25, 31 and 39 are in lower position, thereby applying current from conductor 34 through contacts 41, 43, 33, 36, 26 and 27 to conductor L_3, energizing antennas 3 and 3′ to produce the field pattern F_3 in Fig. 2 for the interval of one dot. During the next following $\frac{1}{10}$ revolution the lobe 38 of cam 18 elevates the follower 39 to connect conductor 34 through contacts 40 and 42 to conductor L_2, thereby energizing antennas 2 and 2′ to produce the field pattern [illegible] in Fig. 2 for an interval of one dot after which follower 39 drops off lobe 38 and for the next three-tenths of a revolution of shaft 21 all three followers 25, 33, and 29 are in lowermost position, thereby connecting conductor 34 through contacts 41, 43, 33, 36, 26 and 27 to conductor L_3 to energize antennas 3 and 3′ and produce the field pattern F_3 in Fig. 2 for an interval of three dots. During the next three-tenths of a revolution (which restores the shaft 21 to the starting point), the follower 25 is in elevated position, while followers 31 and 39 are in lowermost position, thereby connecting conductor 34 over contacts 41, 43, 33, 36, 26 and 28 to conductor L_1, energizing antennas 1 and 1′ to produce the field pattern F_1 in Fig. 2 for an interval of three dots.

Referring now to Fig. 3 this diagram shows the nature of the signals that will be transmitted in different directions from the general location 0 of the antenna system shown in Fig. 1 in response to the operation of the switching system, and directive antennas described. The area surrounding the antenna location 0 is shown divided into four large segments Q_a, Q_d, Q_u and Q_n, respectively, these segments being hereinafter referred to as quadrants. Small segments C_{ad}, C_{du}, C_{un}, and C_{na}, interposed between the four quadrants, will be hereinafter referred to as courses. The signals produced in the quadrant Q_a result only from field F_3 in Fig. 2. The signals produced in the opposite quadrant Q_u are produced by both field F_3 and field F_4. The signals produced in quadrant Q_n result only from field F_1 and the signals in quadrant Q_d result from the fields F_1 and F_2.

The signals that will be heard in course C_{na} are the combined signals produced by the overlapping fields F_1 and F_3 in Fig. 2. The signals produced in course C_{ad} will be a combination of the signals produced by overlapping fields F_3, F_1 and F_2. The signals produced in course C_{du} will be the combined signals produced by the overlapping fields F_3 and F_1 and F_4 and F_2. The signals produced in the course C_{un} will be the combined signals resulting from the overlapping fields F_1, F_3 and F_4.

Referring now to Fig. 4 the horizontal row of dots and dashes, identified by the letter D, represent the sequence of signals transmitted in the quadrant Q_d of Fig. 3; the horizontal row of dots and dashes opposite the letter U represent the sequence of signals transmitted in the quadrant Q_u of Fig. 3; the horizontal row of dots and dashes opposite the letter N represent the sequence of signals in the quadrant Q_n of Fig. 3; and the horizontal row of dots and dashes opposite the letter A represent the sequence of signals in the quadrant Q_a of Fig. 3. It will be noted that if the dots and dashes in row D of Fig. 4 are added to the dots and dashes in row U a continuous signal DU results which will indicate the signal transmitted along course C_{du} in Fig. 3. If the impulses in rows U and N of Fig. 4 are added, the resultant signal UN is a series of long dashes separated by single spaces, which is the signal transmitted in course C_{un}.

Referring again to Fig. 4, if the signal impulses in row N are added to the signal impulses in row A, the resultant signal NA consists of alternate long and short dashes separated by a single space. This is the signal which exists along course C_{na} in Fig. 3. If the signal impulses in row A and the signal impulses of row D in Fig. 4 are combined, the resultant signal AD is a series of long dashes separated by short spaces identical with the signals UN.

The production of the signals as shown in Fig. 4 by the system shown in Fig. 1, may be readily followed through by observing that the shaft 21 in Fig. 1 is in the position shown at the instants T_0, T_{10}, and T_{20} indicated in Fig. 4, the latter figure showing the signals produced during three complete cycles of operation of the cam mechanism in Fig. 1.

It will be apparent from the foregoing discussion that the dot-dash signal representing the letter A will be repeatedly transmitted in the quadrant Q_a of Fig. 3, and that the dash-dot-dot signal representing the letter D will be repeatedly transmitted in the quadrant Q_d. These signals, overlapping each other in the course C_{ad} will produce in that course a series of long dashes separated by single spaces. The code signal dot-dot-dash, representing the letter U, will be repeatedly transmitted in the quadrant Q_u and these signals will combine with the dash-dot-dot signals of quadrant Q_d to produce in the course C_{du} a continuous, steady signal. The code dash-dot representing the letter N will be repeatedly transmitted in the quadrant Q_n and these signals will combine with the dot-dot-dash signals of quadrant Q_u to produce in the course C_{un} a series of long dashes separated by short spaces similar to the signals produced in course C_{ad}. The dot-dash signals in quadrant C_a will combine with the dash-dot signals in quadrant C_n to produce in the course C_{na} a signal consisting of alternate short and long dashes separated by single spaces.

It will be apparent, therefore, that a different code signal will be received in each of the four quadrants Q_a, Q_d, Q_u and Q_n. Likewise different code signals will be produced along the three courses C_{na}, C_{ad}, and C_{du}. With the system shown, however, the code received along the course C_{un} will be the same as that received along course C_{ad}.

It will be observed that the dot-dash code signal for the letter A, produced in quadrant Q_a, results solely from energization of antennas 3 and 3′ in Fig. 1 and that the production of the dash-dot code signal in quadrant Q_n is produced entirely in response to energization of the antennas 1 and 1′ in Fig. 1. However, the dot-dot-dash code signal transmitted in quadrant Q_u is produced by both antennas 3 and 3′ and antennas 4 and 4′. Thus the antennas 4 and 4′, which produce the cardioid field F_4 in Fig. 2, transmit the first dot of the signal, which dot is not transmitted in quadrant Q_a because of the unidirectional characteristics of antennas 4 and 4′. The remainder of the signal in the quadrant Q_u is a dot and dash identical with the complete signal in quadrant Q_a. Therefore the code signal for the letter U of quadrant Q_u is completed by adding to the dot transmitted from antennas 4 and 4′ the dot-dash which is transmitted in two directions from antennas 3 and 3′.

Similarly, the dash-dot signal in the quadrant Q_n and the dash-dot-dot signal in quadrant Q_d are produced by first transmitting a dash-dot in both directions from antennas 1 and 1' and then transmitting one dot only in the direction of quadrant Q_d from the unidirectional antenna array comprising antennas 2 and 2'.

In Fig. 2, for purposes of clarifying the diagram, the cardioid field patterns F_4 and F_2 are shown of lesser extent than the juxtaposed lobes of the figure-8 patterns F_3 and F_1, respectively. However, it is to be understood that in practice the field strength of the fields F_4 and F_2 will be substantially the same as those of fields F_3 and F_1.

For the purpose of explaining my invention, a specific embodiment thereof has been indicated schematically and described in detail. However, it will be apparent to those skilled in the art that numerous changes and modifications can be made in the particular arrangement shown, and the invention is therefore to be limited only as set forth in the appended claims. It should be noted particularly that other code signals and other combinations of code signals than those disclosed, may be employed.

I claim:

1. The method of producing a radio range having differently coded signals in diagonally opposite sectors, which comprises transmitting a radio wave simultaneously in two diammetrically opposite directions to produce a complete unitary code signal in one sector and part of a different unitary code signal in the opposite sector, and transmitting a radio wave in said opposite sector only to complete said different code signal in said opposite sector.

2. A radio beacon comprising a first means for transmitting signals predominately in one direction only and a second means for transmitting signals equally in two opposite directions, one of which directions is the same as the direction of transmission of said first means, means for energizing said two transmitting means alternately in predetermined timed relation to repeatedly transmit a single predetermined different code signal in each of said two opposite directions, the signal transmitted in said one direction only supplementing the signal transmitted in both of said directions to form the single predetermined code signal transmitted in said one direction.

3. A radio beacon comprising a first means for radiating waves predominately in one direction, a second means for radiating waves equally in two opposite directions, one of which is the same as said first direction, a third means for radiating waves predominately in one direction at a substantial angle to said first direction, and a fourth means for radiating waves predominately in two opposite directions, one of which is identical with said third direction, and means for successively and repeatedly energizing said four radiating means in predetermined order to repeatedly transmit a single predetermined different code signal in each of said four different directions.

4. The method of producing a radio range having different identification in different sectors in a horizontal plane, comprising: transmitting radio waves horizontally in a plurality of overlapping sectors from a central point, differently interrupting the waves transmitted in two overlapping sectors to produce different telegraphic code signals in said two different sectors, the signals in the two sectors being complementary to each other, whereby the radio wave is continuous in the region of overlap, and differently interrupting the waves in the two respective sectors of a second pair of sectors to form code telegraph signals that are relatively short and not completely complementary whereby the radio wave is discontinuous in the region of overlap of said second pair of sectors.

5. A radio beacon comprising: means for transmitting a telegraph code signal in a first quadrant, means in addition thereto for transmitting a second code signal in the third quadrant diagonally opposite said first quadrant, which second signal includes as a component thereof the same signal transmitted in said first quadrant, means for transmitting a third code signal in the second quadrant between said first and said third quadrants different from the code signals in the first and third quadrants, and means in addition thereto for transmitting a fourth code signal in the fourth quadrant diagonally opposite said second quadrant, which fourth signal includes as a component thereof the same code signal transmitted in said second quadrant.

6. A radio beacon comprising means for radiating a plurality of overlapping sectors of directionally radiated energy, defining courses in the regions of overlap, means for characterising pairs of sectors of energy by identical signals, the sectors of each pair being oppositely disposed, and means for radiating additional signals in one of each pair of said sectors to change the identity of the first-mentioned signal therein and give a unique signal of identification to each sector.

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