June 5, 1934. H. DIAMOND 1,961,206

TWELVE-COURSE, AURAL TYPE, TRIPLE MODULATION DIRECTIVE RADIOBEACON

Filed Oct. 29, 1932 4 Sheets-Sheet 1

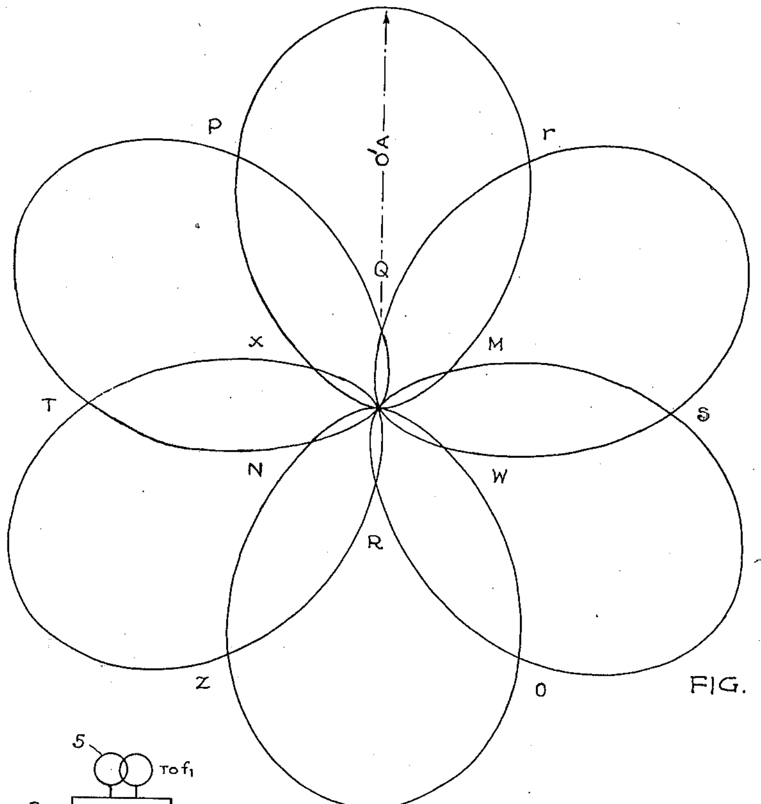

FIG. 1.

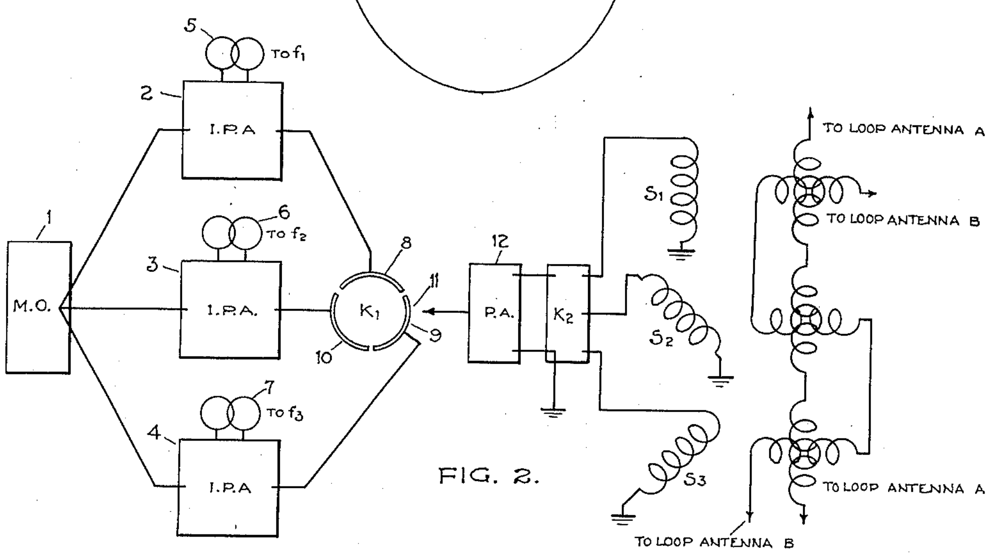

FIG. 2.

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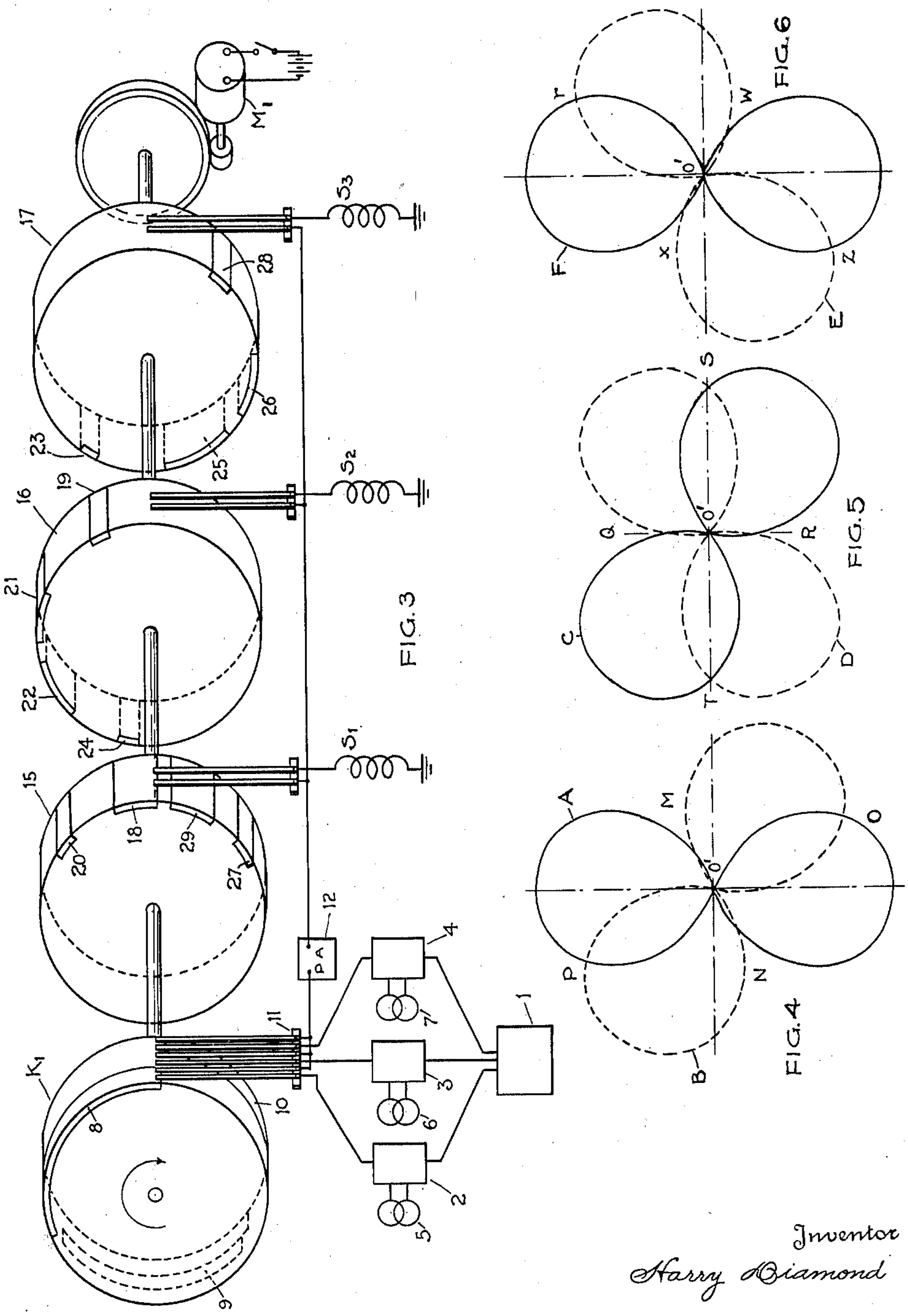

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TWELVE-COURSE, AURAL TYPE, TRIPLE MODULATION DIRECTIVE RADIOBEACON

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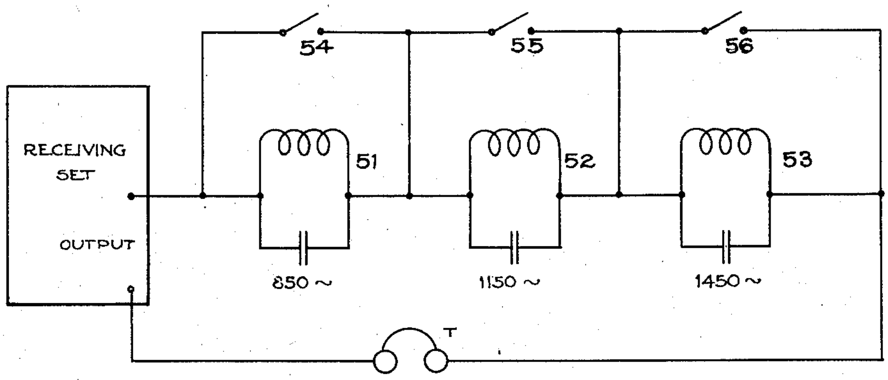

FIG. 7

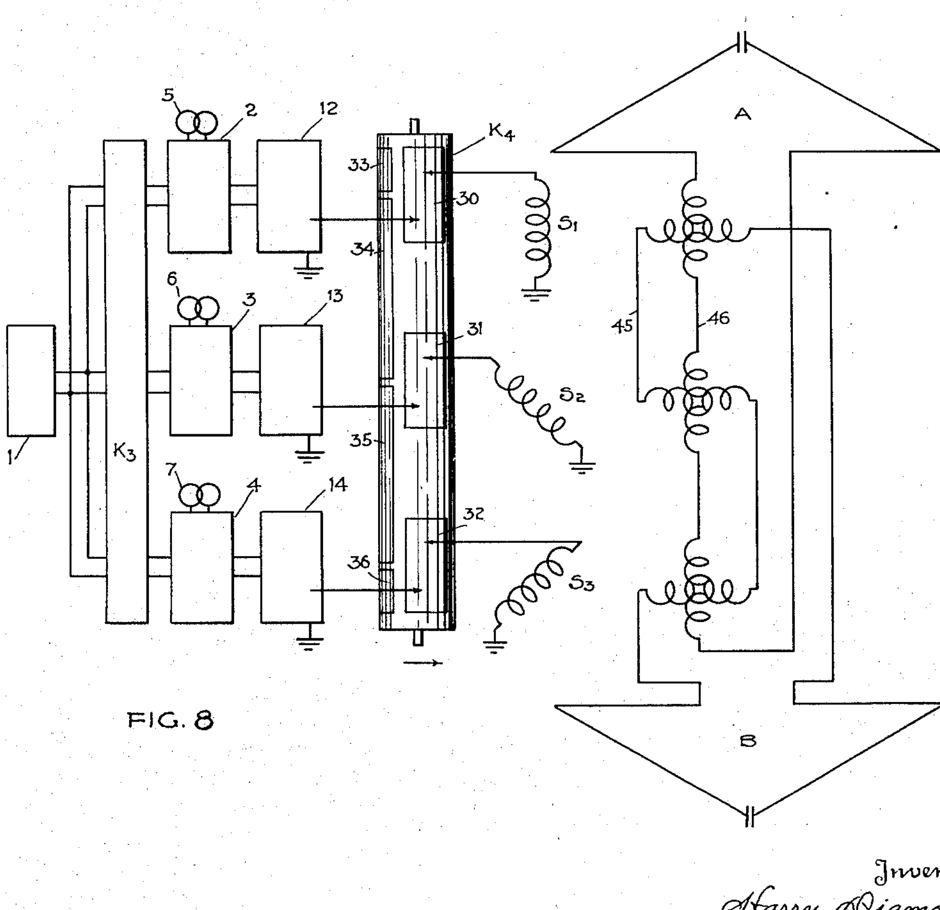

FIG. 8

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TWELVE-COURSE, AURAL TYPE, TRIPLE MODULATION DIRECTIVE RADIOBEACON

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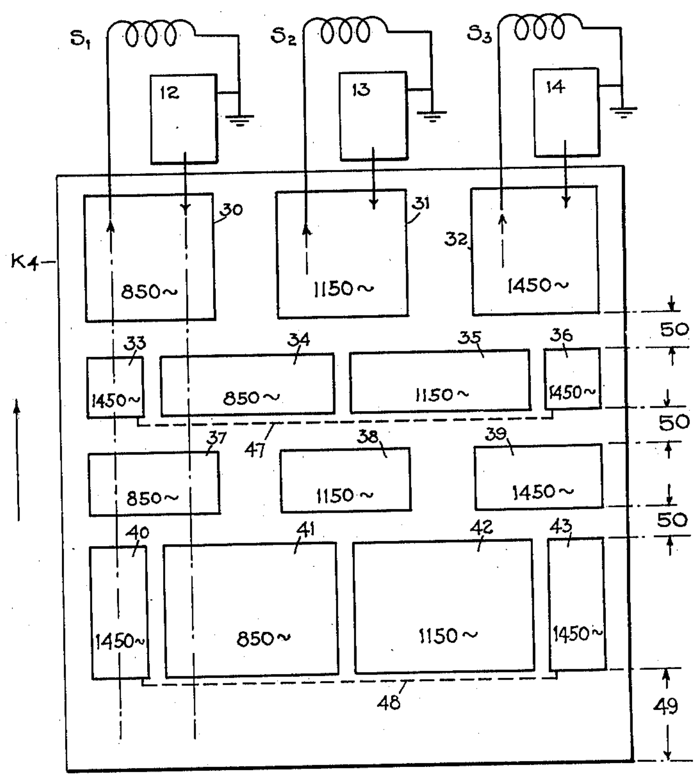

FIG. 9

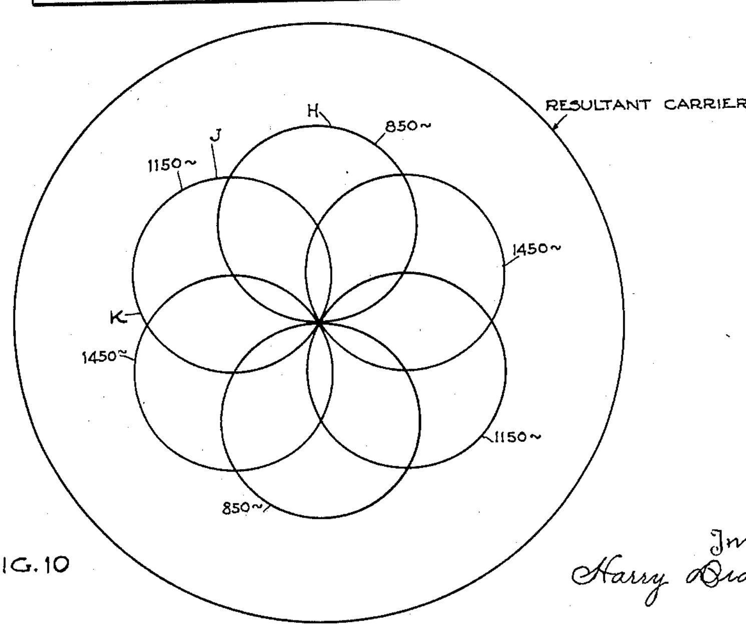

FIG. 10

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Patented June 5, 1934 **1,961,206**

UNITED STATES PATENT OFFICE

1,961,206

TWELVE-COURSE, AURAL TYPE, TRIPLE MODULATION DIRECTIVE RADIO-BEACON

Harry Diamond, Washington, D. C., assignor to the Government of the United States represented by the Secretary of Commerce

Application October 29, 1932, Serial No. 640,154

8 Claims. (Cl. 250—11)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

The invention described herein may be manufactured and used by or for the Government of the United States for governmental purposes only without the payment of any royalty thereon.

This invention relates to improvements in the aural type directive radio beacon systems and particularly to means whereby the number of courses can be increased to serve more than four airways simultaneously.

An object of this invention resides in the provision of an improved method and circuit arrangement therefor wherein two interlocked coded signals are transmitted in a plurality of successive groups, the carrier in each group being modulated to a different low frequency and the radiated space patterns of said groups oriented to yield twelve useful radio beacon courses.

Another object is to provide a method and circuit arrangement therefor whereby two interlocked coded signals are transmitted in a plurality of groups all transmitted simultaneously. The carrier of each group being modulated to a different low frequency and the radiated space patterns thereof oriented to yield twelve useful radio beacon courses.

Other objects and advantages of my invention will be evident from the following descriptions taken in connection with the accompanying drawings, in which,

Figure 1 is a polar diagram for a twelve-course visual directive radio beacon, and is intended to illustrate why it has hitherto been considered impossible to secure a twelve-course aural type beacon.

Figure 2 is a schematic diagram of a transmitting system embodying one method of my invention whereby three groups of interlocked signals are transmitted successively.

Figure 3 is a detailed drawing of the switching arrangements indicated by K_1 and K_2 in Figure 2.

Figures 4, 5, and 6 show the received polar patterns corresponding to the three 120° segments of K_1.

Figure 7 is a schematic diagram of the circuit arrangement attached to the radio receiver.

Figure 8 shows a schematic diagram of a transmitting system embodying my invention in an arrangement differing from that shown in Figure 2.

Figure 9 is a developed detailed drawing of the keying switch shown in Figure 8.

Figure 10 is a polar pattern showing the carrier and side bands transmitted by the transmitting arrangement of Figure 8.

In my previous application for U. S. patent Serial No. 597,757, and joint application Serial No. 597,756, the triple-modulation directive radio beacon using tuned-reed visual indication is described, and shown to yield twelve useful courses normally disposed 30° from each other. Methods for shifting these courses to align them to the airways are also described therein.

An inherent advantage of the visual beacons which makes its use desirable is that twelve courses disposed at approximately 30° with each other may be obtained rather than the four courses at 90° with the aural beacons. The twelve courses are made possible by the selectivity introduced by the vibrating reeds used for reception.

Reference to Figure 1 which is a diagram of the received polar pattern for the twelve-course visual type directive-radio beacon will illustrate this point. Thus courses, M, N, Q, R, W, and X would not be possible if the two reeds indicating a given course were to any extent affected by the third modulating frequency employed. Suppose that aural coded signals were used. At a given course (say course Q) the two desired signals, the relative magnitudes of which indicate the course position, would obviously be masked by the strong signal (O'A). It has, therefore, been assumed to date that a twelve-course aural type directive radio beacon is impossible.

As noted in the foregoing, the object of my invention is to describe two separate circuit arrangements whereby twelve-beacon courses of the aural type normally displaced 30° from each other, may be obtained. The circuit arrangements herein described should prove of considerable value at airports located at the junction of more than four airways.

The transmitting system shown in Figures 2 and 3 comprises a master oscillator 1, tuned to the carrier frequency say, 290 kc. and connected for supplying radio frequency voltage in equal amounts to the grids of the intermediate amplifier tubes 2, 3 and 4. The output of each intermediate amplifier is modulated to a different frequency, say, 850, 1150 and 1450 cycles by the modulators 5, 6 and 7, respectively. The modulated output of each intermediate amplifier tube is then transferred successively to a single power amplifier tube 12 by means of a three-segment switch K_1. Three circuit closing segments 8, 9 and 10, are mounted on a revoluble cylinder of insulating material, arranged to cover successive thirds of the cylinder and displaced laterally to close each pair of contacts 11 (Fig. 3) consecutively for one third of a revolution of the cylinder. The coded signals are produced by connecting the output of a power amplifier tube 12 to the stator coils in consecutive groups of two by means of a switch K_2 which consists of metallic contacts mounted on the non-conducting cylinders 15, 16, and 17 whereby each group of stator windings is energized alternately for short intervals of time, the time of duration of each contact determining the signal desired. The three-segment switch K_1 and the code cylinders 15, 16 and 17 are mounted on the same shaft and rotated in a clockwise direction by the motor M_1. For example, to produce the coded signals for the group of stator coils consisting of S_1 and S_2 the intermediate power amplifier 2 is connected to the power amplifier tube 12 through the segment 8. The output of 12 is then connected to S_1 and S_2 alternately by means of the sliding contacts 18, 19, 20, and 21 in the order named. The time of contact is adjusted so that the stator coil S_1 is excited to the coded signal (— .) and the stator coil S_2 is excited to the coded signal (. —), the two signals being interlocked and modulated to the same low frequency (850 cycles).

When the revoluble segment 9 connects the intermediate power amplifier tube 3 to the power amplifier tube 12, a second group of interlocked signals modulated to 1150 cycles is produced by connecting the stator coils S_2 and S_3 alternately to the power amplifier 12 by means of the revoluble circuit closers 22, 23, 24, and 25 in the order named. Likewise when the intermediate amplifier tube 4 is connected to 12 by the revoluble contact 10, a third group of coded signals modulated to 1450 cycles is produced by the stator coils S_3 and S_1, by connecting the output of 12 alternately to S_3 and S_1 by means of the revoluble contacts 26, 27, 28 and 29 in the order named. The power from the excited stator coils is transferred to the loop antennas A and B by means of the inductive relations existing between the goniometer stators and rotor windings.

For a given position of the goniometer rotor, each stator winding in conjunction with the two rotor windings and the two crossed loop antennas is equivalent to a single phantom loop antenna whose plane coincides with the plane of the stator. Since the three stator windings are crossed at 120 degrees, the three phantom loop antennas are also crossed at 120 degrees. For the first third of a revolution of switch K_1, the received polar pattern shown in Figure 4 will be obtained, in which A denotes the received pattern of the phantom antenna due to stator S_1 modulated to 850 cycles and excited to the coded signal (— .) and B denotes the corresponding pattern of the phantom antenna due to S_3 modulated to 850 cycles and excited to the coded signal (. —). The two signals are interlocked. Courses exist along the lines PO′, QO′, MO′, and NO′ where the two signals have the same intensity.

The two signals are so interlocked that an observer located on one of these lines obtains only long dashes. Were he not on one of these lines, he would receive a preponderance of either signal (— .) or (. —) depending upon his position with respect to the course.

For the second third of a revolution of switch K_1, the received pattern shown in Figure 5 will be obtained, in which C denotes the received pattern of the phantom antenna due to the stator S_2 modulated to 1150 cycles and excited to the coded signal (— .) and D denotes the corresponding pattern of the phantom antenna due to S_3 modulated to 1150 cycles and excited to the coded signal (. —). The courses exist along the lines SO, TO, QO, and RO.

For the last third of a revolution of the switch K_1 the received pattern shown in Figure 6 will be obtained, in which E denotes the received pattern of the phantom antenna due to the stator S_3 modulated to 1450 cycles and excited to the coded signal (— .) and F denotes the corresponding pattern of the phantom antenna due to S_3 modulated to 1450 cycles and excited to the coded signal (. —). The courses exist along the lines rO, wO, xO, and zO. These are repeated successively as the switch K_1 rotates. Three sets of four courses each, the three sets being displaced by 30 degrees from one another, are thus secured.

It remains necessary to select any one of these three sets of courses in order to make them useful. This is accomplished as shown in Figure 7. Three rejector circuits 51, 52 and 53 tuned to 850, 1150, and 1450 cycles (the three modulation frequencies of the beacon) are employed. The head phones T are connected as shown. If the courses shown in Figure 4 are desired, switch 54 is closed. Only the 850-cycle signals are then permitted to pass through the head phones T. To select the courses of Figure 5 the switch 55 is closed. Similarly to obtain the courses shown in Figure 6, switch 56 is closed. A suitable selector switch with a color scheme may be adopted so that with a corresponding color scheme on the route maps, the pilot may easily select the desired set of courses.

A second form of my invention is embodied in the schematic diagram shown in Figure 8. This is essentially the same circuit as for the twelve-course visual type double-modulation directive radio beacon described in my above mentioned applications for patents with the addition of a keying switch K_4.

During the operation of a radio beacon of this type, a master oscillator 1 supplies a carrier frequency voltage of, say, 290 kc. to the grids of the intermediate power amplifiers 2, 3 and 4, equal in magnitude but differing in phase by 120°. The phase difference is introduced by means of a coupling and switching unit K_3 which is the phase splitting arrangement described in connection with an application for a patent on the twelve course visual type radio range-beacon Serial No. 597,756 referred to above, my switching unit, K_3 together with the master oscillator form what is essentially a three-phase radio frequency oscillator.

The intermediate power amplifier tubes 2, 3 and 4 are modulated to three different frequencies (say 850, 1150, and 1450, respectively). Their modulated output is then transferred to the power amplifiers 12, 13 and 14, respectively, where it is further amplified for exciting the goniometer stator coils S_1, S_2 and S_3 to coded signals. The intermittent closing of the goniometer circuits is accomplished by means of a plurality of metallic contacts 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42 and 43 mounted on a cylinder of insulating material, K_4.

The arrangement of the metallic contacts on the switching cylinder K_4 is shown in detail in Figure 9 which is a surface of revolution showing all contacts. The arrow indicates the direction of rotation.

The goniometer stator coils are excited to the coded signals as follows: Assume the cylinder K_4 in the position shown in Figure 8. Referring to Figure 9, the power amplifier tubes 12, 13 and 14 are connected to the goniometer stator coils S_1, S_2 and S_3 respectively, by means of the first row of metallic contacts 30, 31 and 32. The cylinder rotating in a clockwise direction then connects the power amplifier tubes 12, 13 and 14 to the stator coils S_2, S_3 and S_1, respectively, by means of the second row of metallic contacts 33, 34, 35, and 36. The contacts 33 and 36 are connected by a conductor, indicated by the dash line 47. Further rotation of the cylinder connects 12, 13 and 14 to S_1, S_2 and S_3, respectively, by means of the third row of metallic contacts 37, 38 and 39 (Fig. 9). Still further rotation connects 12, 13 and 14 to S_2, S_3 and S_1, respectively, by means of the fourth row of metallic contacts 40, 41, 42 and 43. Contacts 40 and 43 are connected by the conductor indicated by the dash line 48, Figure 9. It will be observed that the time of duration of the contact for the first and fourth rows of contacts is twice the length of the second and third row, the longer contacts corresponding to coded dash signals and the shorter contacts to coded dot signals. The spaces 50, during which the stator windings S_1, S_2 and S_3 are not connected to the power amplifier tubes 12, 13 and 14 are really much shorter than indicated in Figure 9, so that the interruption between the dots and dashes are minute. However, the space 49 (during which no connections obtain) is fairly long for a reason which will appear in the following.

A study of the different operations accomplished by the switching mechanism K_4, remembering that the power amplifier 12 is always modulated to 850 cycles, 13 to 1150 cycles, and 14 to 1450 cycles, will indicate the following results:

During each revolution of the switching cylinder K_4, radio-frequency power modulated to 850 cycles is impressed upon stator winding S_1 in accordance with the coded characteristic (— .) and upon stator winding S_2 in accordance with the characteristic (. —), the two characteristics being interlocked. This is followed by a space during which neither stator is excited, corresponding to space 49.

Similarly during each revolution of K_4, radio-frequency power modulated at 1150 cycles is impressed upon S_2 in accordance with the coded characteristic (— .) and upon S_3 in accordance with the characteristic (. —), the two characteristics being interlocked. An interval of no transmission, corresponding to space 49, is again obtained.

Furthermore, during each revolution of K_4, radio-frequency power modulated at 1450 cycles is impressed upon S_3 in accordance with the characteristic (— .) and upon S_1 in accordance with the characteristic (. —), which are also interlocked. The space of no transmission, corresponding to 49 of course also obtains.

It will be observed that the (— .) transmission from stators S_1, S_2 and S_3 all occur at the same time while the (. —) transmission from the three stators also occur simultaneously. However, the use of the receiving circuit arrangement shown in Figure 7 permits the selection of any of the three modulation frequencies and the rejection of the other two. For example, if the 850 cycle signal is selected, the (— .) signal received corresponds to the space pattern set up by excitation of the stator winding S_1, while the (. —) signal corresponds to the space pattern produced by exciting stator winding S_2.

The total radiated space pattern is shown in Figure 10. It consists of a resultant carrier K and three figure-of-eight side band characteristics H, J and K, yielding three sets of four courses each. The received pattern obviously consists of the three patterns shown in Figures 4, 5 and 6 transmitted simultaneously. The use of radio-frequency switching between the master oscillator 1 (see Fig. 8) and the intermediate amplifiers 2, 3 and 4 insures that no distortion of the space pattern due to intercoupling between stator windings S_1, S_2 and S_3 will exist.

By means of my method and apparatus it is possible to establish twelve useful "aural" radio beacon courses whereas previously to my invention only four courses were possible, my apparatus being designed to transmit three groups of coded signals in such a way that the human ear may pick out one of these three with the aid of an earphone or the like. My apparatus also provides a means whereby three groups of coded characteristics may be transmitted along three groups of beacon courses.

What I claim is:

1. A method of transmitting directive radio signals to produce twelve equisignal courses from a radio beacon along a plurality of different lines of direction radiating from said beacon, which comprises transmitting three successive groups of interlocking signals on the same carrier frequency but each group having a different modulation frequency, each of said groups of interlocking signals producing a set of four equisignal courses, and orienting a plurality of courses to align them with a plurality of airway routes intersecting at an airway beacon.

2. A method of producing twelve equisignal courses from a radio beacon along a plurality of different lines of direction radiating from said beacon which comprises transmitting simultaneously two interlocked coded signals in a plurality of groups, the carrier wave of each group being supplied from a common source and modulated to a low frequency which is different from each of the plurality of groups, each of said groups of interlocking signals producing a set of four equisignal courses, and orienting a plurality of said courses to align them with a plurality of airway routes intersecting at an airway beacon.

3. A method of transmitting directive radio signals to produce a plurality of equisignal courses from a radio beacon along a plurality of different lines of direction radiating from said beacon, which comprises transmitting a plurality of successive groups of interlocking signals on the same carrier frequency, but each group having a different modulation frequency, each of said groups of interlocking signals producing a set of equisignal courses, and orienting a plurality of courses to align them with a plurality of airway routes intersecting at an airway beacon.

4. A method of producing a plurality of equisignal courses from a radio beacon along a plurality of different lines of direction radiating from said beacon which comprises transmitting simultaneously two interlocked coded signals in a plurality of groups, the carrier wave of each group being supplied from a common source and modulated to a low frequency which is different for each of a plurality of groups, each of said groups of interlocking signals producing a set of four equisignal courses, and orienting a plurality of said courses to align them with a plurality of airway routes intersecting at an airway beacon.

5. A method of providing radiobeacon service along a plurality of different lines of direction radiating from a common central point, which comprises transmitting from that point on a single carrier frequency three successive groups of interlocked coded signals each of a different modulation frequency, orienting the figure-of-eight space patterns corresponding to each of the two interlocking signals of each of said groups in different directions to produce a set of four equisignal courses, and selecting at the receiving end any desired one of the three resultant sets of equisignal courses by detecting the radiobeacon signals and rejecting from a signal responsive device all signals except those having a modulation frequency corresponding to the desired group.

6. A method of providing radiobeacon service along a plurality of different lines of direction radiating from a common central point, which comprises transmitting from that point simultaneously three groups of interlocked coded signals, the carrier wave of each group being supplied from a common source and modulated to an audio-frequency which is different for each of the three groups, orienting the figure-of-eight space patterns corresponding to each of the two interlocking signals of each of said groups in different directions to produce a set of four equisignal courses, and selecting at the receiving end any desired one of the three resultant sets of equisignal courses by detecting the radiobeacon signals and rejecting from a signal responsive device all signals except those having a modulation frequency corresponding to the desired group.

7. In a radiobeacon the combination with a source of radio-frequency power, of three intermediate amplifiers fed in parallel from said source and each modulated to a different audio frequency, a power amplifier, a switching device adapted to impress in succession upon said power amplifier the output of each of said intermediate amplifiers, a goniometer comprising three fixed stator windings crossed at 120 degrees and two rotor windings crossed at right angles and rotatable about a common axis with respect to said stator windings, two crossed loop antennas tuned to the radio frequency of said source and connected each in series with one of said goniometer rotor windings, an output switching device interposed between said power amplifier and said goniometer to connect said goniometer stator windings to the output of said power amplifier in groups of two, said output switching device operating in synchronism with said first-named switching device, so that the radio-frequency power received by each group of two stator windings corresponds to the amplified modulated output of a corresponding one of said intermediate amplifiers, means associated with said output switching device for coding said two stator windings of each group to interlocked coded signals whereby the two stator windings acting in conjunction with the two rotor windings and the two loop antennas set up two figure-of-eight space patterns each coded to a different characteristic and both having the same modulation frequency thereby producing a set of four equisignal courses, and means for driving said input and output switching devices whereby corresponding to the three successive positions of said switching devices three sets of four equisignal courses each are radiated, each set being characterized by a distinctive audio-frequency modulation.

8. In a radiobeacon the combination with a source of radio-frequency power, of three intermediate amplifiers, a radio-frequency switching device interposed between said source of radio-frequency power and said intermediate amplifiers for cyclically exciting said amplifiers, modulation devices for modulating each of said intermediate amplifiers to a different audio-frequency, three power amplifiers for separate amplification of the modulated power output of each of said intermediate amplifiers, a goniometer comprising three fixed stator windings crossed at 120 degrees and two rotor windings crossed at right angles and rotatable about a common axis with respect to said stator windings, two crossed loop transmitting antennas tuned to the radio-frequency of said source and connected each in series with one of said goniometer rotor windings, an output switching device interposed between said power amplifiers and said goniometer having three sets of contactors and auxiliary brushes, each of said sets operating to feed power from one of said power amplifiers to a corresponding pair of said goniometer stator windings alternately and in accordance with two interlocked coded signals so that the two stator windings acting in conjunction with the two rotor windings and the two crossed loop antennas produce two figure-of-eight space patterns each coded to a different characteristic and both having the same modulation frequency thereby producing a set of four equisignal courses, and associated means on said output switching device for synchronizing the switching from each of said power amplifiers to the corresponding pairs of goniometer stator windings whereby the antenna system radiates simultaneously three sets of four equisignal courses each set being characterized by a distinctive audio-frequency characteristic.

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