June 13, 1933. H. DIAMOND ET AL 1,913,918

TRIPLE MODULATION DIRECTIVE RADIO BEACON SYSTEM

Filed March 9, 1932 2 Sheets-Sheet 1

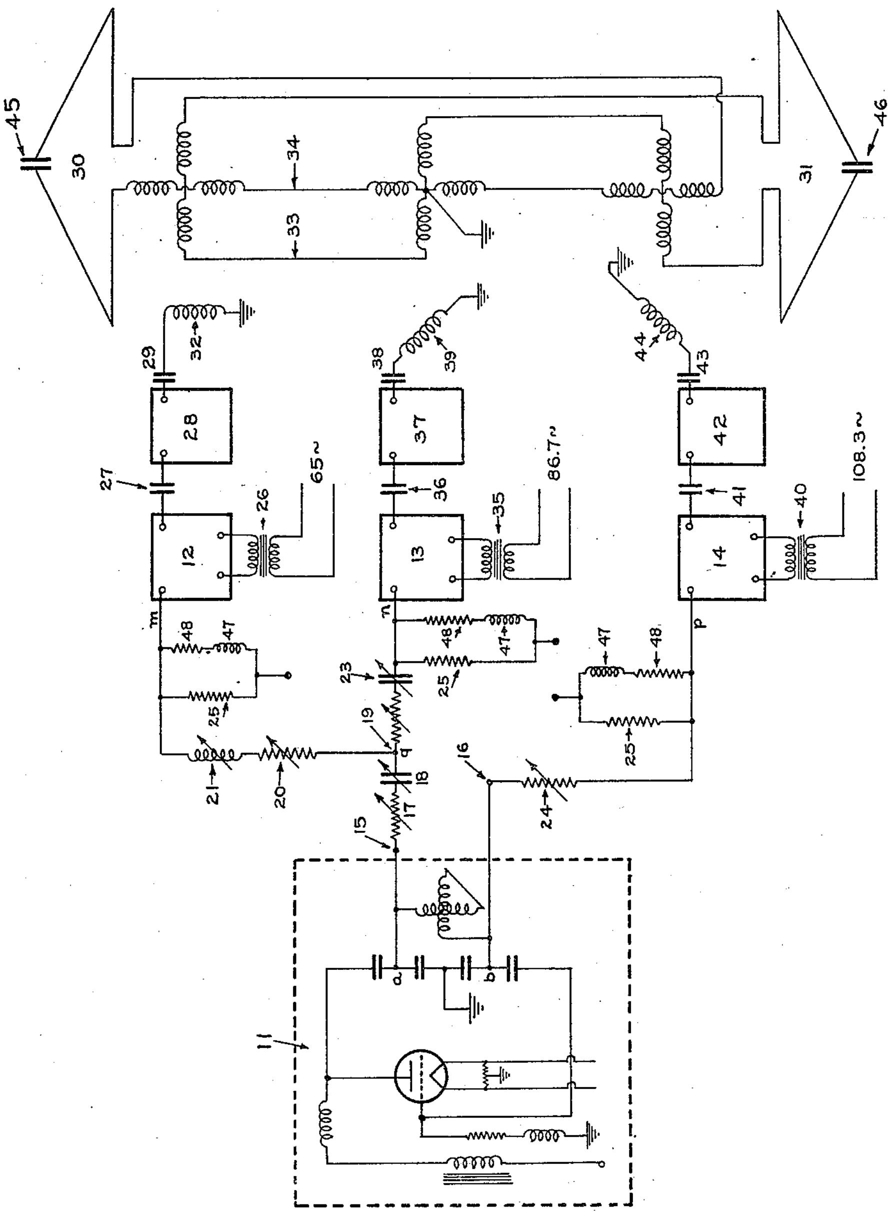

FIGURE 1

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TRIPLE MODULATION DIRECTIVE RADIO BEACON SYSTEM

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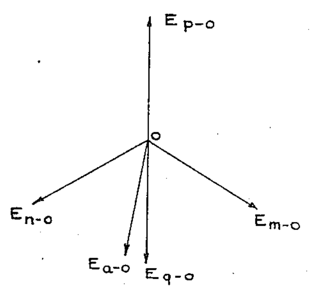

FIGURE 2

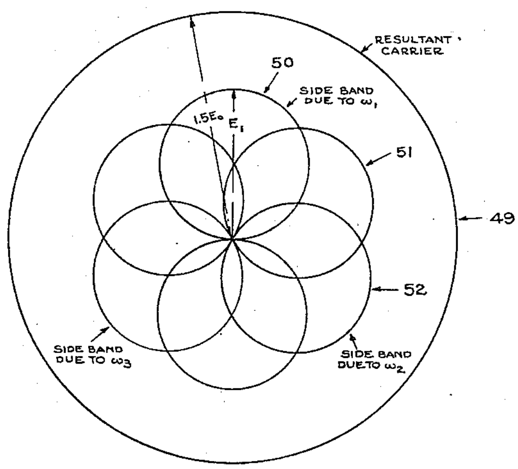

FIGURE 3

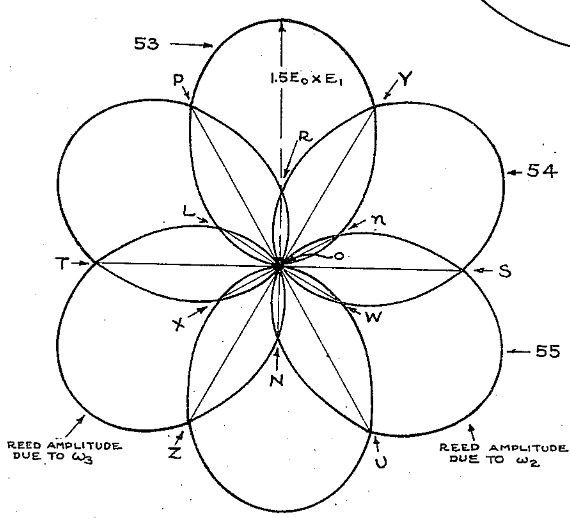

FIGURE 4

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UNITED STATES PATENT OFFICE

HARRY DIAMOND, OF WASHINGTON, DISTRICT OF COLUMBIA, AND FRANK G. KEAR, OF MINERSVILLE, PENNSYLVANIA, ASSIGNORS TO THE GOVERNMENT OF THE UNITED STATES, AS REPRESENTED BY THE SECRETARY OF COMMERCE

TRIPLE-MODULATION DIRECTIVE RADIO BEACON SYSTEM

Application filed March 9, 1932. Serial No. 597,756.

(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.

The invention relates to improvements in the method and apparatus for producing directive radio beacon signals, utilizing a single transmitter and antenna system, capable of serving more than four courses simultaneously.

Another object of our invention is to provide means for aligning the beacon courses to the airways.

In a copending application of Harry Diamond, Serial No. 597,757, filed March 9, 1932, for U. S. patent, the triple-modulation directive radio beacon is described and shown to yield twelve useful courses normally disposed 30 degrees from each other. Methods for shifting the courses to align them to the airways are also described.

The invention herein described utilizes certain of the desirable features of the invention set forth in the application referred to, together with other novel features whereby further desirable results are secured.

The transmitting system disclosed in the application referred to involves inefficient and cumbersome equipment difficult to adjust and involving considerable loss of power, as for example, the use of link circuits to eliminate coupling between stator windings and the need for supplying an auxiliary carrier to replace the one suppressed by the goniometer systems. These circuits are critical in their adjustment since satisfactory results can only be obtained when the vertical antenna is in accurate phase adjustment with respect to the beacon carrier frequency.

The substitution of means for exciting but one stator winding at a time simplifies the circuits but with an attendant loss of power. The net power transmitted by each amplifier branch, when using a grid-biasing arrangement for switching radio-frequency supply successively to each amplifier train at an audio-frequency rate, is reduced considerably below the normal; primarily because power is transmitted only during approximately one-half of the time, and secondly, because during that time the operating point travels along the tube characteristic from the point of cut-off to the point of normal operation and back to the cut-off point.

Our purpose is to simplify the apparatus and render it more efficient for use at the junction of a large number of airways, capable of serving from one to twelve air routes simultaneously.

The use of 3-phase audio-frequency for switching the radio-frequency power as described above suggested that the same results could be obtained if a source of 3-phase radio-frequency were available. Each phase of this 3-phase radio-frequency supply could then be used for supplying carrier voltage to the grid of one intermediate amplifier, the 3-phase source thus serving as a master oscillator as well as a switching device.

A circuit accomplishing the desired object was constructed and will be described hereinafter with the results obtained.

As will appear from the following description, the advantages to be gained through the use of radio frequency switching are fourfold: (*a*) a decided increase in the power transmitted by each amplifier branch; (*b*) the elimination of a three-phase audio-frequency unit or of anti-coupling devices; (*c*) the operation of the intermediate amplifier tubes under normal conditions and not with the high grid voltages necessary in the method of grid-bias switching; and (*d*) the elimination of interference caused by the audio-frequency used for grid biasing.

Referring to the drawings, Figure 1 is a schematic diagram of the transmitter and antenna system of the triple-modulation directive radio beacon, using the method of radio frequency switching embodying our invention.

Figure 2 shows the voltage vector diagram for the three-phase radio-frequency master oscillator arrangement employed in Figure 1.

Figure 3 shows the beacon space pattern when using 3-phase radio-frequency switching.

Figure 4 shows the received polar pattern corresponding to the space pattern of Figure 3.

The novel features of our invention will now be described more in detail with the aid of Figure 1 which is a schematic diagram of the triple-modulation directive radio beacon utilizing a phase-splitting arrangement for obtaining three-phase radio-frequency switching. The numeral 11 is a conventional form of master oscillator which produces a continuous wave carrier, which is connected for supplying radio-frequency voltage in equal proportions to the control grids of the three intermediate amplifier tubes 12, 13 and 14. Two conductors are connected to the oscillator at the points 15 and 16 for the purpose of conducting the radio-frequency current to the amplifier tubes. Advantage is taken of the fact that the voltages at these two points to ground are approximately 180 degrees out of time phase. A non-inductive resistor 17 and a capacitor 18 are inserted in series with one conductor to advance the time-phase of its radio-frequency current in order to compensate for the effect of load upon the 180 degrees phase difference between the two points 15 and 16. After passing through the adjustable capacitor 18, the current is again divided at 19 into two branches, some passing through a non-inductive resistor 20 and an inductor 21 to the grid of the intermediate amplifier tube 12 and an equal amount passing a non-inductive resistor 22 and a condenser 23 to the intermediate amplifier tube 13. The current from the second conductor, connected to point 16, passes through a non-inductive resistor 24 to the intermediate amplifier tube 14. The values of the non-inductive resistor 20, the inductor 21, the non-inductive resistor 22 and the condenser 23 are so chosen that the voltage applied to the input circuits of the intermediate amplifiers 12 and 13 are equal in magnitude and displaced by 120 degrees in time-phase from each other. Moreover, the voltage applied to the input circuit of intermediate amplifier 12 lags the voltage between point 19 and ground by 60 degrees and the voltage applied to the amplifier 13 leads the voltage between points 19 and ground by 60 degrees. The value of resistor 24 is so chosen that the voltage applied to the intermediate amplifier 14 is equal in magnitude to the voltages applied to the amplifiers 12 and 13. Since the time-phase displacement between points 16 and 19 is exactly 180 degrees, it is evident that the voltages applied to the three intermediate amplifiers are respectively 120 degrees apart in time-phase. As will be explained below, the time-phase displacement between the voltages applied to the grids of the three intermediate amplifying tubes must remain constant to prevent a shifting of the beacon courses in space. A variation of the grid to filament tube impedances would tend to cause such a displacement. The resistances 25 (having values of 7500 ohms) are connected in parallel with the grid to filament impedances to minimize such variation. With this arrangement, a 20 per cent change in the grid to filament impedance of any tube results in but a 2 degree variation in the time-phase displacement. Similarly, a change in the oscillator frequency of 2 kc results in a 0.2 degree time-phase variation. These are well within the permissible limits.

The output of tube 12 is modulated by means of a 65-cycle source of constant frequency supplied by the transformer 26 which is connected to a suitable source of alternating current supply. The modulated radio frequency output of tube 12 passes through a condenser 27 to the grid of a power amplifier tube 28. The amplified modulated high frequency current then passes through a condenser 29 and is transferred to antennas 30 and 31 through the inductive coupling between a stator 32 and the rotors 33 and 34.

By a similar series of transformation, the output of the intermediate amplifier tube 13 is modulated by means of an 86.7-cycle source of constant frequency supplied by a transformer 35 which is connected to a suitable source of alternating current supply. The modulated radio-frequency output then passes through a condenser 36 to a power amplifier tube 37, a condenser 38, and is transferred to the antennas 30 and 31 through the inductive coupling between a stator 39 and the rotors 33 and 34. Likewise, the output of the intermediate amplifier tube 14 is modulated by means of a 108.3-cycle source of constant frequency supplied by a transformer 40 which is connected to a suitable source of alternating current supply. The modulated radio-frequency output then passes through a condenser 41, a power amplifier tube 42, a condenser 43 and is transferred to the antennas 30 and 31 through the inductive coupling between the stator 44 and the rotors 33 and 34. The loop antennas 30 and 31 are tuned to the master oscillator frequency by means of the condensers 45 and 46, respectively. Proper grid bias is supplied to the intermediate amplifier tubes by means of a 220 volt direct current generator, (not shown) through radio-frequency chokes 47 and non-inductive resistors 48.

It is to be noted that although we used only one combination of modulating frequencies in the description of the preferred circuit, it is understood that any other suitable combination may be employed.

The theory of operation of the transmitting circuit arrangement described in Figure 1 may now be considered. The modulated voltages applied to the three stator coils 32, 39 and 44 are displaced by 120 degrees in time-phase. It is to be noted that intercoupling between stator windings does not exist since the stators are excited but one at a time owing to this 120 degrees time-phase displacement. Each stator, acting in conjunction with the two crossed rotor coils and the two crossed loop antennas, sets up a system which is electrically equivalent to a single loop antenna. For zero rotor setting, the plane of this phantom antenna coincides with the plane of the stator coil considered. Since there are three stator windings, normally disposed at 120 degrees to each other, three such phantom antennas (also crossed at 120 degrees) exist, each phantom antenna carrying current of the same radio-frequency, but modulated to a different low frequency. The carriers in the three phantom antennas being 120 degrees out of phase, both in time and in space, a revolving field is set up, the resultant carrier space pattern being a revolving figure-of-eight of constant magnitude.

The beacon space pattern obtained when using radio-frequency switching is shown in Figure 3, which consists of three figure-of-eight side band characteristics and a circular carrier 49. 50 indicates the figure-of-eight side band characteristic from the stator 32 modulated at 65 cycles, 51 indicates a similar characteristic from the stator 44 modulated at 108.3 cycles, and 52 indicates a similar characteristic from the stator 39 modulated at 86.7 cycles. The carrier is here represented as circular, this circle being the locus of successive maxima of the rotating figure-of-eight actually produced.

The corresponding polar pattern assuming square-law detection is shown in Figure 4, in which 53 shows the figure-of-eight reed amplitude characteristic due to the 65-cycle modulation. 54 and 55 show similar characteristics due to the carrier frequencies modulated at 86.7 and 108.3 cycles, respectively. The courses lie along the lines LO, XO, TO, ZO, etc. Twelve courses are obtained, normally placed 30 degrees from one another.

Note that even for the same power transmitted by each amplifier branch this system yields 50 per cent greater received signal than the system employing grid-bias switching described in the companion application. With grid-bias switching the carrier due to each phantom loop-antenna (E_0) beats with its side-band frequency (E_1) in the process of detection, yielding a resultant audio-frequency of magnitude proportional to $E_0 \times E_1$. In the case of radio frequency switching, the carrier which beats with each set of side bands, say E_1, is 1.5 E_0 as is evident from Figure 3. Consequently the resultant audio frequency signal received is $1.5\ E_0 \times E_1$.

The patterns of Figures 3 and 4 are for the special case when the three stator windings are exactly 120 deg. apart in space phase and the three voltages applied to these stators exactly 120 deg. apart in time phase. As will be observed, the carrier comprises a figure-of-eight revolving in space at the carrier-frequency rate. The curve representing the carrier in Figure 3 is in reality the locus in space of successive maxima of the rotating figure.

It should be noted that each set of side bands transmitted by one amplifier branch beats with its own carrier and also with the in-phase components of the other two carriers of the system.

A departure of the three carrier voltages from exact 120-deg. time-phase displacement results in a shifting of the beacon courses in space. It is therefore desirable to keep the phase displacement between the three phases of the radio frequency power substantially constant.

The same means are available for shifting the beacon courses from their 30-deg. space relationship (in order to align them with the airways emanating from a given airport) as have been described in the companion application.

What we claim is:—

1. In a directive radio beacon, the combination with a master oscillator, of three amplifying branches, means for converting a single phase radio frequency supply from said master oscillator into a three phase radio frequency supply, means for using each phase of said three phase source for supplying carrier power to a particular one of said amplifier branches, a means of modulating the carrier wave in each of said branches to a low frequency differing for each branch, a directive antenna system comprising two directive antennas crossed at right angles to each other, and means for transferring the modulated waves in succession from each of said three amplifier branches to said directive antenna system whereby said three modulated waves are transmitted in predetermined directions to provide a multi-course beacon space pattern.

2. In a directive radio beacon, the combination with a master oscillator, of three amplifying branches, means for converting a single phase radio frequency supply from said master oscillator into a three phase radio frequency supply, means for using each phase of said three phase source for supplying carrier power to a particular one of said amplifier branches, a means of modulating the carrier wave in each of said branches of a low frequency differing for each branch, a directive antenna system comprising two directive antennas crossed at right angles to each other, means for transferring the modulated waves in succession from each of said three amplifier branches to said directive antenna system whereby said three modulated waves are transmitted in predetermined directions to provide a multi-course beacon space pattern, and means for modifying the

resultant space pattern whereby the directions of a number of beacon courses may be changed to align them with a plurality of airway routes converging on a radio beacon station.

In testimony whereof we affix our signatures.

HARRY DIAMOND.
FRANK G. KEAR.