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A METHOD OF PROVIDING COURSE AND QUADRANT IDENTIFICATION WITH THE RADIO RANGE-BEACON SYSTEM

By F. W. Dunmore

ABSTRACT

Certain circumstances may arise, especially when near the radiobeacon, when a pilot may pass from one course or quadrant to another without his knowledge of it. When once so lost, he may wander many miles in an attempt to reorient himself, since the 4 courses are all practically identical, and 2 of the 4 quadrants between the courses give identical indications. This paper describes a method of obviating this difficulty by transmitting a directive signal composed of 1 dot in a westerly direction, a similar signal of 2 dots in an easterly direction, 3 dots north, and 4 dots south. Depending upon which set of these signals is the loudest, a pilot may determine his general direction from the beacon. Methods of transmitting these signals with practically no interruption to the visual beacon signals and during the station identification interruption of the aural beacon are described.

The change from the figure-of-eight transmission for the courses to the unidirectional cardioid transmission may be accomplished either by changing the point of coupling into suitable phasing sections in the transmission line feeding the antenna or by superimposing on a figure-of-eight radiation through a suitable hybrid coil circular radiation in phase with the figure-of-eight radiation. Standard relays operated by a motor-driven dot-sending device serve to make these changes. In the latter method a simple reversing relay serves to reverse the direction of transmission of the cardioid signals in a given set of antenna systems.

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I. INTRODUCTION

In the radio range-beacon system now used on the airways the determination of absolute direction or position is difficult. Certain circumstances may arise, especially when the aircraft is near the radio beacon, when a pilot may pass from one quadrant or course to another without his knowledge of it. When once so lost, it becomes a very difficult matter for him to reorient himself and he may wander many miles from the beacon in the attempt. His course indications may show him to be in either of two quadrants or on any one of four courses; he does not know which. Only by a laborious method involving flying over a considerable distance [1] can he reorient himself. In fact, tests have shown that the average pilot when flying under the hood and purposely lost requires about an hour to get on a known course. A radio range-beacon should not only function to keep a pilot on a definite course, which the present system does admirably, but it should also provide means whereby in case he does become lost be may readily orient himself and get on a known course. This paper outlines a means for doing this without any extra equipment on the airplane and with but slight modification at the radiobeacon. Flight tests at the Bureau's experimental field at College Park, Md., have shown that a pilot may easily reorient himself when lost, by means of this system.

II. PRINCIPLE OF OPERATION

The system as worked out assumes the range-beacon to be equipped with the new TL antenna now being installed at many radio range-beacon stations.[2] The 4 quadrants and 4 courses are identified by 4 aural signals each transmitted in a different direction.

Referring to figure 1, *B* and *C* represent the usual beacon figure-of-eight directional transmissions; each may be modulated at a different audio frequency, as in the case of the visual beacon system, or coded with "*A*" and "*N*" signals interlocked as with the aural beacon system, and produce courses *D*, *E*, *F*, and *G*. The antennas of the TL antenna system for producing the figure-of-eight radiation characteristics shown at *H*, *I*, *J*, and *K*, are preferably arranged to coincide with the four cardinal points of the compass. *L*, *M*, *P*, and *Q* are the respective transmission lines. By properly phasing the currents in antennas *H* and *J* by means of phasing sections in transmission lines *L* and *P* (to be described later), an aural signal *R*, consisting of a dot, may be transmitted in a westerly direction with a directional transmission characteristic similar to the shape of a cardioid. In a like manner (see fig. 2) a similar signal, *S*, consisting of 2 dots, may be sent in an easterly direction; similarly, a 3-dot signal, *T*, sent north, and then a 4-dot signal, *U*, sent south. Figure 3 shows each identification signal as it is sent separately. From the relative intensities of these different sets of dot signals, which come in the order 1, 2, and 3, 4, a pilot may determine his approximate location with respect to the beacon as illustrated below.

[1] See Air Commerce Bulletin, Sept. 15, 1932, p. 148.

[2] The cause and elimination of night effects in radio range-beacon reception, H. Diamond, B.S.Jour. Research, vol. 10 (RP513), p. 7, January 1933. On the solution of the problem of night effects with the radio range-beacon system, H. Diamond, Proc. I.R.E., vol. 21, p. 808, June 1933.

III. METHOD OF USING IDENTIFICATION SIGNALS

A pilot may be lost on any one of the four courses of the radiobeacon, in the 65-cycle or *A* quadrant, of which there are 2, or in the 86⅔-cycle or *N* quadrant, of which there are 2. The identification signals tell him which one of the four courses he is on or which one of the four quadrants he is in. For example, referring to figure 2:

(1) Assume the beacon course signals give an on-course indication. This means the pilot may be on any one of the four courses, *OD*, *OE*, *OF*, or *OG*, he does not know which. When the 1-dot, 2-dot identification signal is heard the 1 dot is loud and the 2 dots weak. This places him on course *OE* or *OD*. When the 3-dot, 4-dot signal is heard, the 3 dots are loud and the 4 dots weak. This places him on course *OE* as distinct from course *OD*.

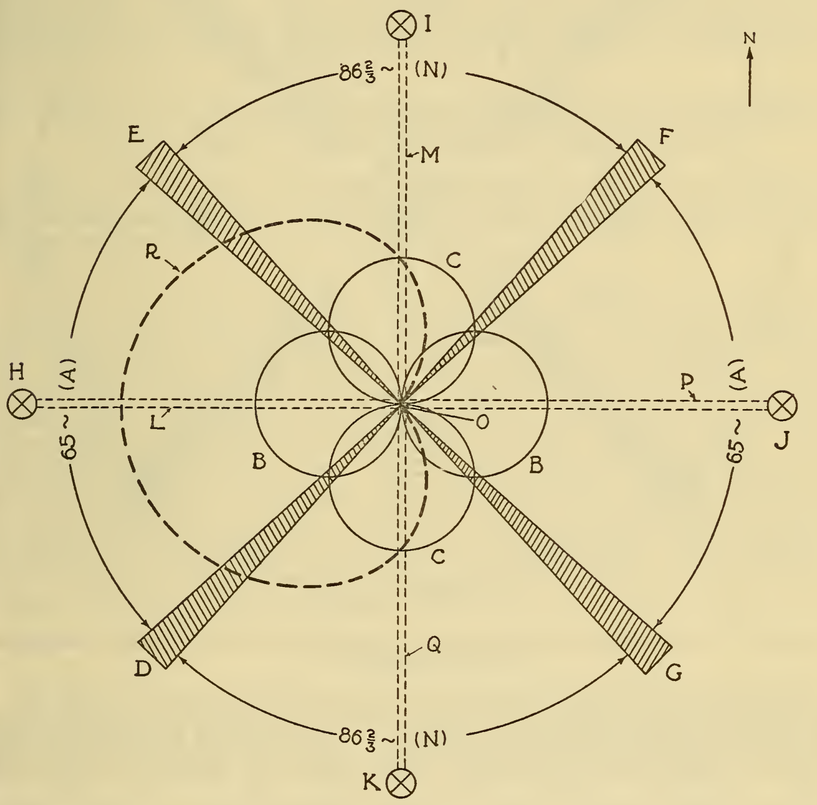

FIGURE 1.—*A single cardioid identification signal showing its relation to the radio beacon courses and quadrants.*

(2) Suppose the beacon-course signal received by the pilot is a strong 86⅔-cycle or *N* signal. This places him somewhere in the region north of the beacon or south of it, not east or west of it. When the dot identification signal is heard, the 1 and 2 dots are about equal, confirming the beacon-course signal indication that the pilot is north or south of the beacon. When the 3- and 4-dot signals are heard, the 3 dots are loud and the 4 dots missing. This places him definitely

in the north (86⅔-cycle) quadrant and not in the south (86⅔-cycle) quadrant, as in the latter quadrant the 3 dots would have been missing, and the 4 dots loud.

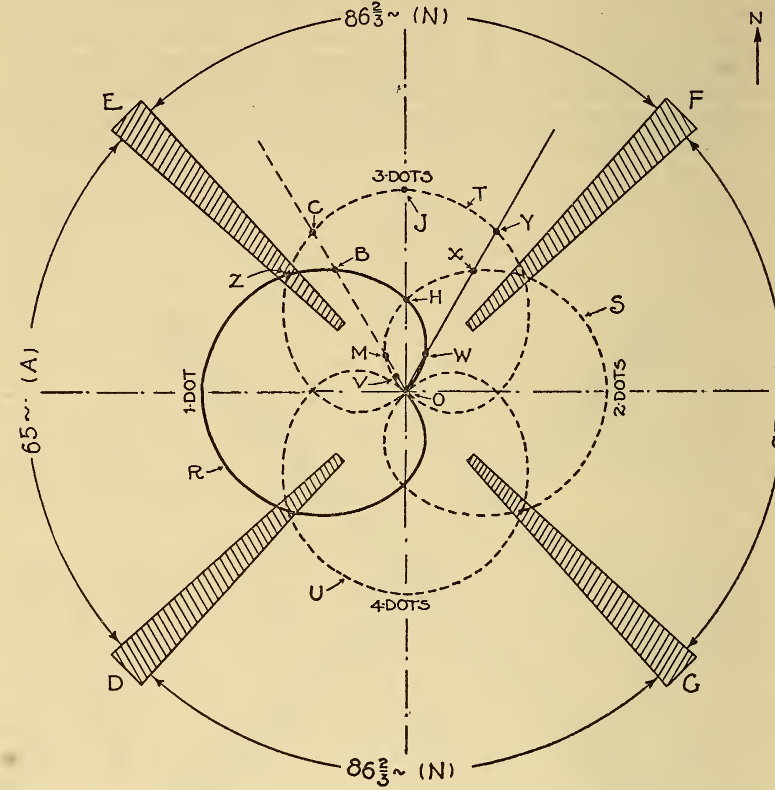

FIGURE 2.—*Chart illustrating the method of interpreting the four cardioid identification signals.*

Not only do the signals tell him which quadrant he is in, but also, in general, what part of the quadrant. Thus, if he is along the line *OY*, the 1 and 2 dots, instead of being equal, are unequal in the ratio

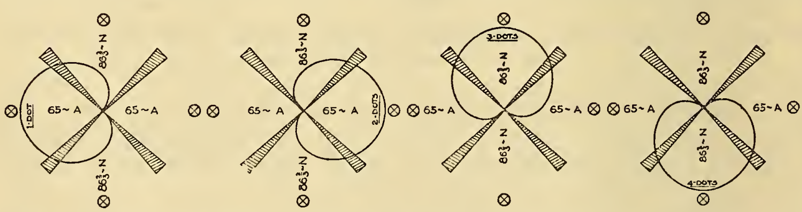

FIGURE 3.—*Chart showing how each cardioid identification signal is sent into a different quadrant.*

of *OW* to *OX*. If he is along the line *OJ*, the 1 and 2 dots are equal in intensity, while along the line *OC*, the 1 dot is louder than the 2 dots in the ratio of *OB* to *OM*.

A further use to which the identification signals may be put is to give the pilot the very necessary information as to whether or not he has passed by the beacon when coming in on a course, in case he should miss the zero-signal zone over the beacon, which indication occurs so quickly that it may easily be missed. Thus, suppose a pilot to be flying in toward the beacon located at O, figure 2 on course *OF*. As long as he remains northeast of the beacon, he hears the 1 dot weak and the 2 dots loud, also the 3 dots loud and the 4 dots weak. The minute he passes over the beacon on to course *OD* southwest of the beacon, the 1 dot becomes loud, the 2 dots very weak, the 4 dots loud, and the 3 dots very weak. Thus, the beacon location may be found with an accuracy depending upon the frequency of transmission of the identification signals.

IV. APPLICATION TO THE VISUAL, AURAL, AND COMBINED VISUAL AND AURAL RADIO RANGE-BEACONS

This method of course and quadrant identification is applicable to any of the aural, visual, or combined aural and visual radio range-beacon systems.

1. AURAL SYSTEM

In the aural system, the set of cardioid directional identification signals is sent when the *A* and *N* course signals are interrupted for the transmission of the beacon station identification letter. The 1-dot, 2-dot signals may be sent during one interruption and the 3-dot, 4-dot signals sent during the next interruption. About 2 seconds are required for the transmission of the 1-dot, 2-dots, and 3 seconds for the 3 and 4 dots. Each set should be repeated once, requiring a total of 10 seconds every 2 or 3 minutes. This repetition is desirable to take care of times when static disturbances are bad. If desired, the four signals may be sent consecutively. This requires twice the time for transmission but doubles the frequency of occurrence of the identification signals.

2. VISUAL SYSTEM

In the case of the visual radio range system, the double-modulation 65-cycle and 86⅔-cycle course signals are interrupted only for the time interval of each dot of the series of identification signals. During the spaces between the dots, the course signal is on again. The identification dot signals are purposely made of very short duration so that the course signals are interrupted for such a short interval of time that the reeds in the visual course indicator have time to drop only about one third their amplitude. As the reeds are equally damped, the relative amplitude of the two reeds does not change during this drop, so that the course indications of the reed indicator are not appreciably affected by the identification signals.

The effect of the identification signals is even less noticeable on the converter type of course indication, as the high damping on the microammeter, used as the course indicator, will not allow the needle to move appreciably during the very short interruption of the beacon course signals. Furthermore, when flying on-course, as is usually the case, the needle is at its null position to which it normally returns when the course signal is not present, which is the case at the instant of sending the dots of the cardioid signal. The 1,000-cycle note comprising the identification signals is kept out of the reed indicator or reed converter circuits, where it might cause interference, by suitable audio filter circuits whereby the 1,000-cycle note is sent to the head phones with very little of the low-frequency course signals and the low-frequency 65-cycle and 86⅔-cycle course signals are sent to the reed indicator or reed converter with very little of the 1,000-cycle identification signals.

3. COMBINED AURAL AND VISUAL SYSTEM

The application to this sytem is a combination of the application to the aural and visual systems. The aural course signals are interrupted for the space of time (10 seconds) required to send two sets

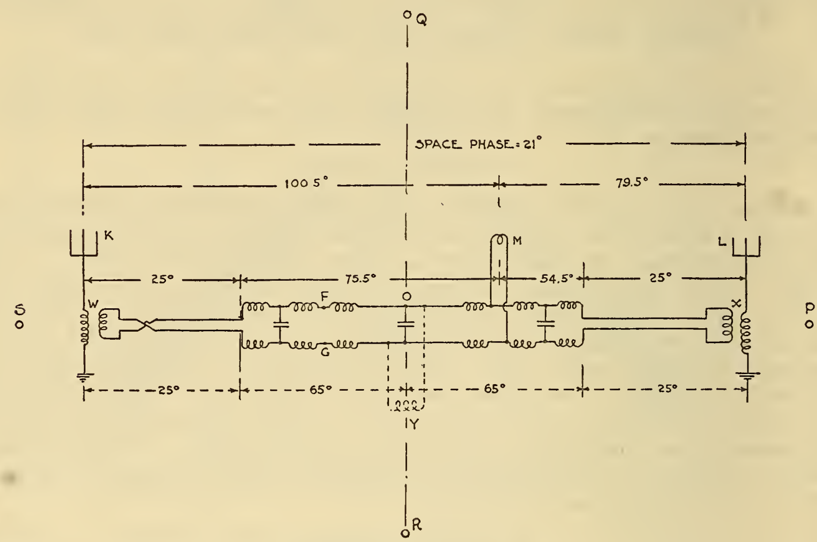

FIGURE 4.—*Method of introducing phasing sections in the transmission lines for obtaining cardioid directional transmission from the* TL *antenna system.*

of identification signals, while visual course signals are interrupted only for the period of each dot.

V. METHOD OF SENDING THE CARDIOIDS FROM THE TL ANTENNA SYSTEM

The cardioid transmission characteristic may be obtained from the TL antenna system in two ways—by supplying current to the 2 antennas in the proper phase, or by supplying current to the 2 antennas 180° out of phase along with a superimposed current in phase in the 2 antennas and of such amplitude and phase relation as to combine with the first 2 currents to give a cardioid transmission characteristic. Figure 4 shows the arrangement used on the experimental beacon at College Park, Md., in making the test on the first-mentioned method. For simplicity, but one set of TL antennas is shown.

1. METHOD OF SECURING THE FIGURE-OF-EIGHT COURSE SIGNALS

For sending the figures-of-eight for the beacon course signals at College Park, the time phase between the point *Y*, figure 4, where the beacon signal power is supplied, and each of the antennas, was made 90° in order to secure phase synchronization of the currents in the 2 antennas.[3] Of this, 25° was in the transmission line and 65° in an artificial line section. As the coupling at *X* is reversed from that at *W*, the current in antenna *L* is 180° out of phase with that in antenna *K*. Thus, at points along the line *QOR*, a minimum signal will be received, while along the line *SOP*, a maximum signal will be received, giving the usual figure-of-eight transmission characteristic for producing the course signals.

2. METHOD OF SECURING THE CARDIOID IDENTIFICATION SIGNALS

(a) METHOD IN WHICH EACH ANTENNA IS SUPPLIED WITH A SINGLE CURRENT OF PROPER PHASE

In this method where the cardioid transmission has a maximum signal in the direction *OP*, figure 4, and minimum signal in the direc-

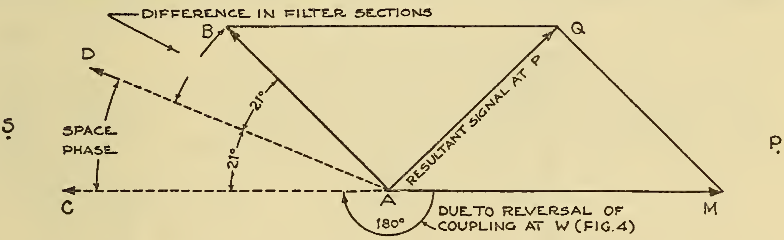

FIGURE 5.—*Phase relation of the signals from the two beacon antennas when sending the cardioid identification signal in the direction of point P.*

tion *OS*, the point of coupling the signal into the artificial transmission line is shifted from *Y* for the course signal to *M* for the cardioid signal. The point *M* is chosen so that a time phase of 100.5° is obtained between *M* and antenna *K*, and 79.5° time phase between *M* and antenna *L*. The reason for the choice of these values is shown below. The space phase between the two antennas as used at College Park was 21°. Referring to figure 5, *AM* represents the signal which would be received at *P* from antenna *L* alone. *AC* represents the signal which would be received at *P* from antenna *K*, not considering the space or time phase betwen the two antennas, but considering the reversal of coupling at *W*. *AD* represents the signal from antenna *K* at *P* considering, in addition, the 21° space phase between the two antennas. *AB* represents the signal from antenna *K* at *P* considering both the reversal of coupling, the space phase, and the 21° introduced by the difference in the electrical length of the artificial lines in the transmission line to antenna *K* and to antenna *L*. This 21° is the 100.5° − 79.5° = 21° shown in figure 4. In other words, *AB* is the signal received at *P* due to antenna *K*. Adding the two vectors, *AM* and *AB*, we get *AQ*, which is the resultant signal received in the direction *OP*. To obtain the signal received in the opposite

[3] Phase synchronization in directive antenna arrays with particular application to the radio range beacon. By F. G. Kear, B.S.Jour. Research, vol. 11, (RP581), p. 123, July 1933.

direction, i.e., at *S*, let *AM*, figure 6, represent the signal received at *S* due to antenna *L*, not considering the space and time phase between the two antennas. *AC* represents the signal which would be received from antenna *K* alone, considering only the reversal of coupling at *W*. Then *AT* represents the signal at *S* from antenna *L* due to a

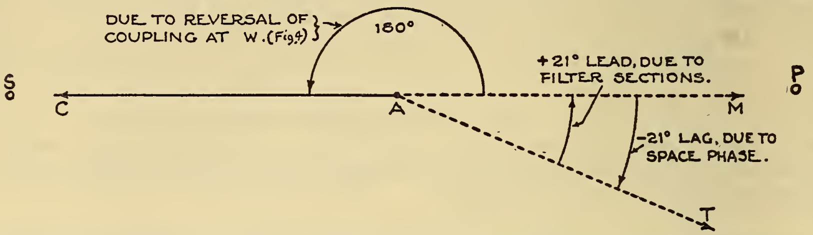

Figure 6.—*Phase relation of the signals from the two beacon antennas when sending the cardioid identification signal in a direction opposite from that to point P.*

21° lag caused by the space phase between the two antennas. Due to the difference in the phasing sections, the current in antenna *L* is given a 21° lead over that in antenna *K*, $+100.5° - 79.5° = +21°$. Therefore, at *S* the currents from *L* and *K* are 180° out of phase and no signal will be received.

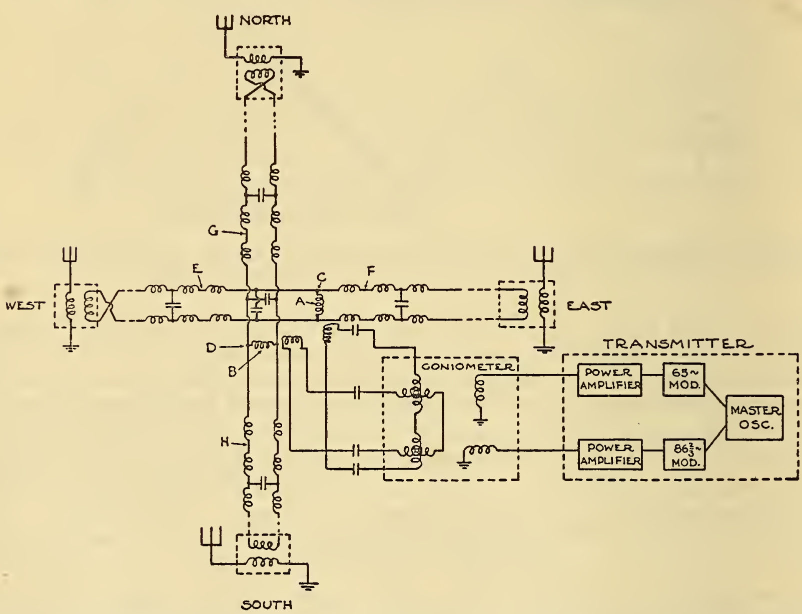

Figure 7.—*Method of reversing the direction of transmission of the identification signals, by connecting input coils A and B to different points in the phasing sections in the transmission lines.*

There are several methods of reversing the direction of transmission of the maximum signal from *P* to *S*. One method adopted is to shift coil *M* to terminals *FG* in the artificial line (see fig. 4), a system of relays making the necessary changeovers. The use of relays in this method is described below.

Circuit arrangement for sending the cardioid dot signals.—A simplified circuit arrangement of a double modulation radio range-beacon with transmission line antenna system is shown in figure 7. The energy from the transmitting set is coupled into the transmission lines through a goniometer and coupling coils *A* and *B*. With the coils *A* and *B* at the points *C* and *D*, respectively, the figure-of-eight course signals are sent. By moving *A* to point *E* and short-circuiting the north-south transmission lines, the phase relations of the currents in the east and west antennas are such that a cardioid directional signal is sent in a westerly direction. By moving coil *A* to point *F*, the phase relations are such that the cardioid signal is sent in an easterly direction. During these cardioid transmissions 1,000 cycles is supplied to the modulator circuits instead of 65 cycles and 86⅔ cycles.

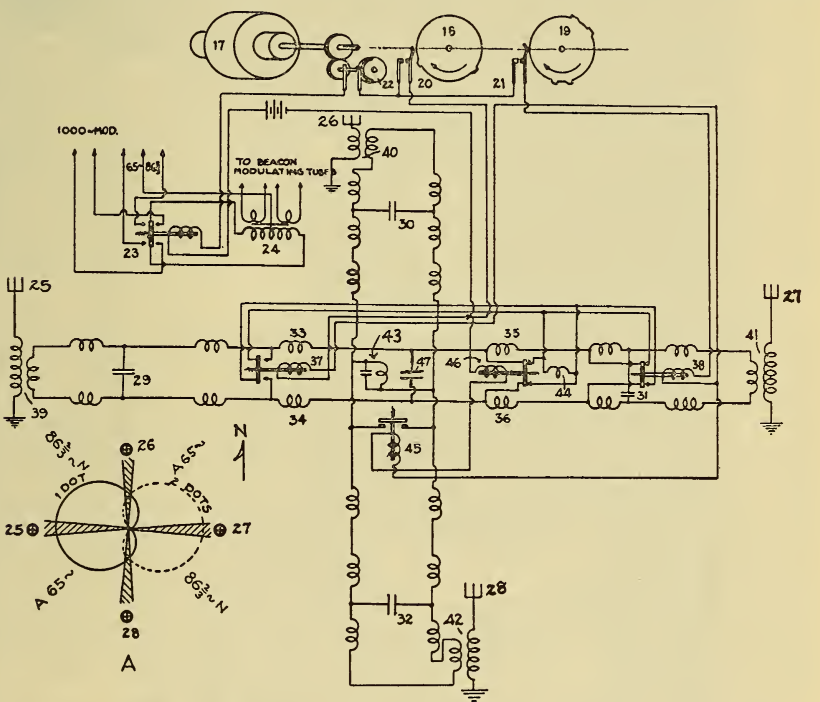

FIGURE 8.—*Circuit arrangement with relays for changing from the figure-of-eight transmission for the courses to the cardioid transmission for quadrant and course identification as applied to one set of antennas.*

In a similar fashion, if coil *B* is moved to point *G* and the east and west transmission line short-circuited, a cardioid signal is sent north, and then south when coil *B* is moved to point *H*.

In order to make the quick changes from the figure-of-eight transmission used for the course signals to the cardioid dot signals and from the 65-cycle and 86⅔-cycle modulation to 1,000-cycle modulation, a system of relays is used to throw the coupling coil *A* from point *C* to *E* or *F* and coupling coil *B* from point *D* to *G* or *H*, and 1,000 cycles on the two modulators in the transmitter.

Figure 8 shows a circuit arrangement with the necessary relays applied to 1 set of antennas for sending 2 of the 4 cardioid signals. This relay system changes to the cardioid transmission only during the period of each dot of the identification signals. In this circuit, 17 is a motor driving the 1-dot sending disk 18 and 2-dot disk 19. 20 and 21 are contacts for making the dots, 22 is a timing switch for sending the cardioid signals as often as desired, 23 is a double-pole double-throw relay operated by contacts 20 and 21 and serves to disconnect the 65-cycle and 86⅔-cycle modulation from the primary of transformer 24, supplying the beacon amplifiers, and supplies 1,000 cycles to this primary during the time of the cardioid transmissions. 25, 26, 27, and 28 are the vertical antennas. 39, 40, 41, and 42 are the coupling units to antennas 25, 26, 27, and 28, respectively. 29, 30, 31, and 32 are the phasing sections in the transmission lines for producing the figure-of-eight transmission for the beacon course signals. 33, 34, 35, and 36 are parts of 29 and 31, respectively, which are thrown into the transmission line feeding antenna 25 or the transmission line feeding antenna 27 by means of the open-circuit type double-pole single-throw relays 37 and 38. Relays 37 and 38 are for producing the cardioid transmission. 43 is a secondary supplying power to antennas 26 and 28; and 44 is a similar secondary supplying power to antennas 25 and 27. 43 and 44 are coupled to the beacon transmitter output through a suitable goniometer. 45 is a single-pole single-throw relay which short-circuits coil 43 rendering antennas 26 and 28 inoperative during the cardioid transmissions from antennas 25 and 27.

During the normal operation of the beacon when the course signals are being sent, contacts 20 and 21 are open, relay 23 is closed on the back contacts, putting 65-cycle and 86⅔-cycle modulation on the beacon amplifiers. Relays 37, 38, and 45 are open, and relay 46 is closed. When the cardioid identification signal is sent, contact 20 closes, relay 23 closes to the right putting 1,000 cycles on the modulating amplifiers, relay 45 closes preventing any radiation from antennas 26 and 28, relay 46 opens taking the radio-frequency power supply from the center of the transmission lines supplying antennas 25 and 27, and relay 37 closes connecting secondary 44 to the opposite side of phasing coils 33 and 34, thus sending a dot cardioid transmission characteristic in the direction of antenna 25. When contact 21 closes, relays 23, 46, and 45 operate as before, but relay 38 closes in place of relay 37, thus sending a 2-dot cardioid transmission in the opposite direction.

In figure 9 is shown the relay and phasing unit as used at the College Park beacon. It is shown removed from its shielding housing and contains the phasing sections 33, 34, 35, and 36, condenser 47, and relays 37, 38, 46, and 45, shown in figure 8.

For sending the full set of 4 identification signals in the 4 different directions, the circuit arrangement in figure 8 should be modified to that shown in figure 10, where the relays and phasing sections shown in the east and west transmission line have been repeated in the north and south transmission lines. A single code wheel—48—with the set of 1-, 2-, 3-, and 4-dot sectors on it, operates the proper relays at the proper time by means of selector brushes 49, 50, 51, and 52. This code wheel is shown in figure 11. This arrangement sends the 1-dot cardioid directional identification signal west, the 2-dot signal east every other revolution of code wheel 48, the 3-dot signal north, and the 4-dot signal south every intermediate other revolution of code wheel

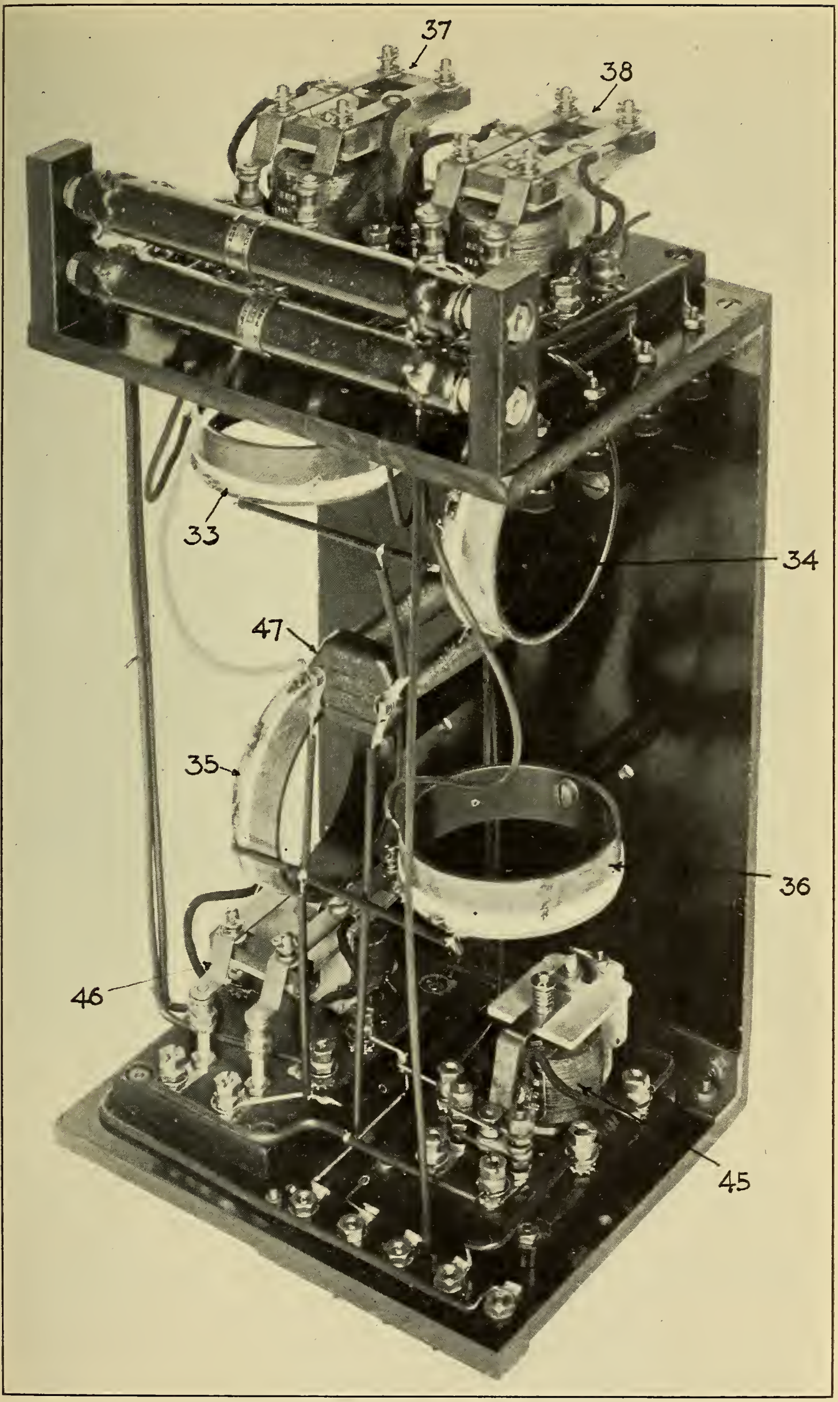

Figure 9.—*A "building out" or phasing section showing relays for altering its position in the transmission line when reversing the direction of transmission of the identification signals.*

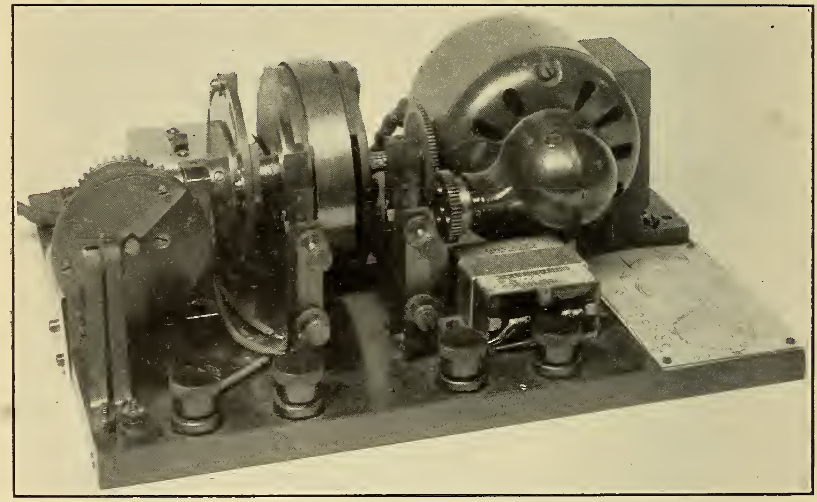

FIGURE 11.—*The coding wheel for making the dot signals in proper sequence.*

48, or, if desired, the full set of signals may be sent each revolution of code wheel 48.

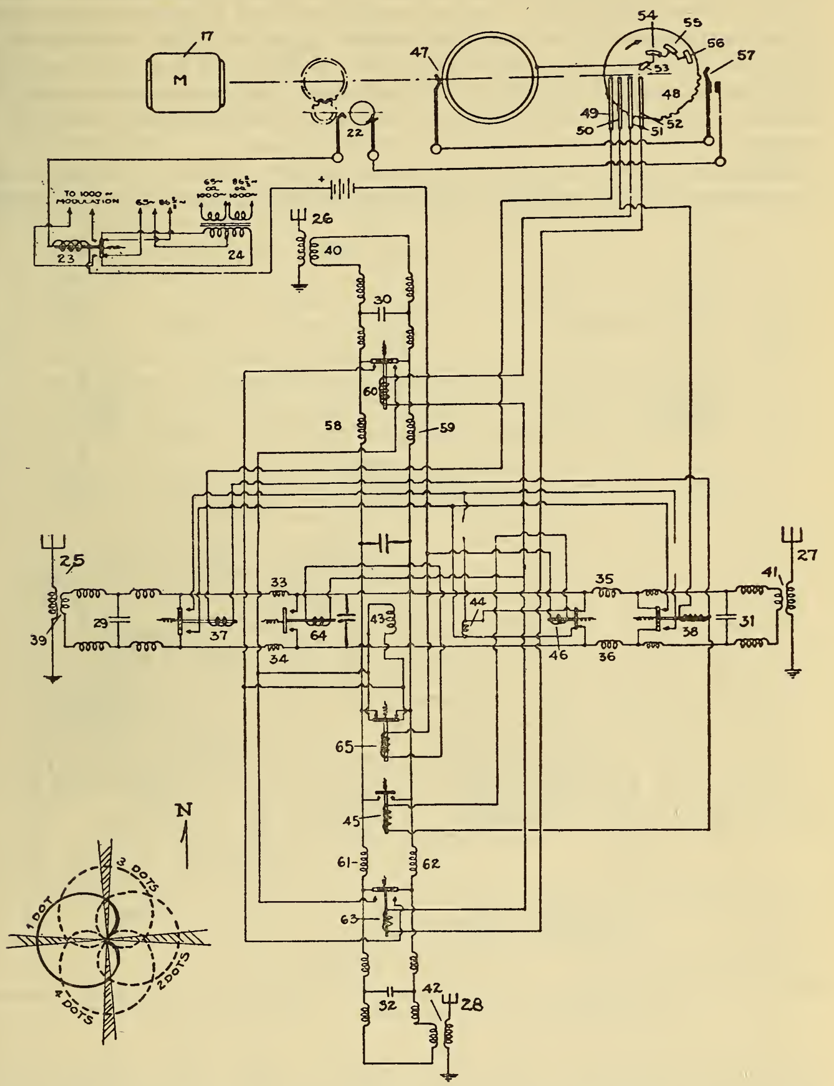

FIGURE 10.—*One of the complete circuit arrangements as used at the experimental beacon station at College Park, Maryland, for sending the course signals and the course and quadrant identification signals.*

(*b*) *METHOD OF SENDING THE CARDIOID SIGNALS BY SUPERIMPOSING IN-PHASE NONDIRECTIONAL RADIATION FROM BOTH ANTENNAS, ON A FIGURE-OF-EIGHT RADIATION FROM THESE ANTENNAS*

This method is better than the one just described, particularly with respect to the stability of the cardioid signal in space and with respect to the ease of adjustment during installation. The cardioid directional characteristic is obtained by combining with the normal figure-of-eight transmission a non-directional transmission in such phase relation to the figure-of-eight transmission that the resultant is a cardioid directional transmission. A split hybrid coil arrangement[4] for coupling into the transmission lines permits maintaining phase synchronization for the normal figure-of-eight transmission, while at the same time adding circular radiation so that the resultant pattern is a stabilized cardioid. Such synchronization gives stability to the directional transmission holding it in its correct location in space.

Figure 12 shows the circuit arrangement for one set of TL antennas as used with this method. The output from the goniometer is sup-

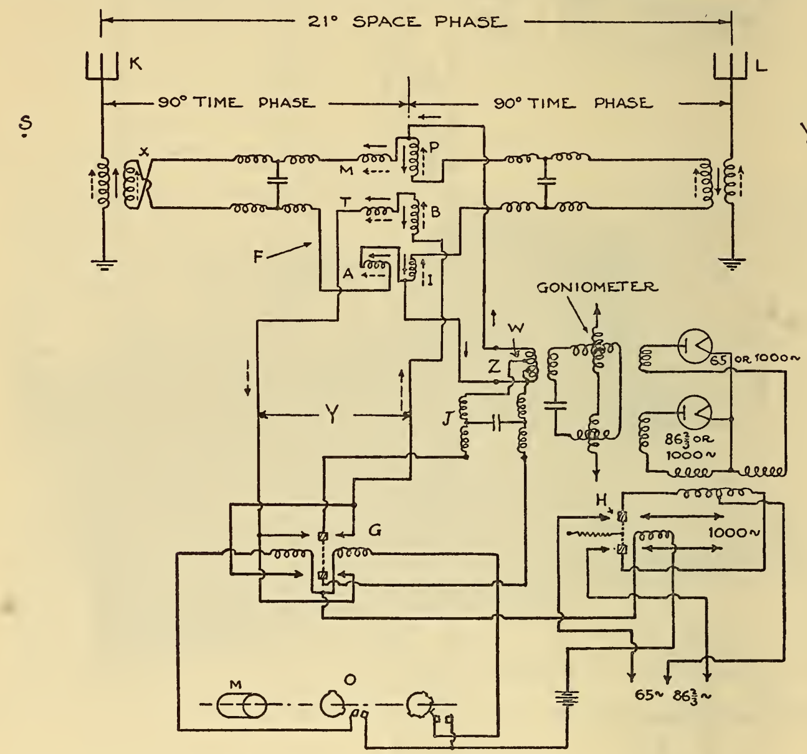

FIGURE 12.—*A simplified system of cardioid transmission in which the direction of transmission may be reversed by a single reversing relay.*

plied to two circuits with inputs *Z* and *Y*. The input supplied at *Z* produces the usual synchronized figure-of-eight transmission characteristic for producing the beacon courses. The input supplied at *Y* produces substantially nondirectional radiation from antennas *K* and *L*. The voltage supplied at *Z* and that supplied at *Y* remains independent due to the use of hybrid coils at *F*. These coils consist of units *M*, *T*, and *A*, all wound in the same direction and closely coupled, and *P*, *B*, and *I* also wound in the same d rection and closely coupled but not coupled to *M*, *T*, and *A*. The connections to coils *A* and *I* are reversed. The full arrows show the circulating currents at a given instant due to the voltage applied at *Z* and the dotted arrows

[4] Suggested by W. E. Jackson, Airways Division, Dept. of Commerce.

show the circulating currents at a given instant due to the voltage supplied at Y. Since the current induced in coil T from A and M is equal and opposite to that induced in coil B due to P and I, none of the voltage impressed at Z will be impressed at Y. Also, since the voltage impressed at Y introduces a clockwise circulating current through both transmission lines in series, and since the lines from Z are connected into the transmission line at a nodal point, none of the voltage impressed at Y will be impressed at terminals Z. The coupling is reversed at X to give a 180° phase displacement of the currents in antenna K and L, as supplied at Z, for the figure-of-eight transmission; and the connections to coils A and I are reversed in order to keep the currents in antennas K and L, as supplied at Y, in phase. As shown by the arrows, the voltage impressed at Z induces instantaneous currents in antennas K and L in opposite directions, giving the figure-of-eight characteristic, while the voltage impressed at Y induces instantaneous currents in these antennas in the same direction, giving the nondirectional radiation. J is a 90° phasing section to produce a phase difference of 90° between the current supplied through line Z and that supplied through line Y. The vector relationship is then such that the combination of the figure-of-eight and circular radiation is a unidirectional transmission characteristic with the shape of a cardioid.

An advantage of this method is the simplicity with which the direction of maximum transmission of the cardioid signal may be reversed. In order to accomplish this it is only necessary to change the phase of the current supplied at Y by 180°. A simple reversing relay, G, serves to accomplish this. With this relay open, no signal is supplied at Y, and with a second relay, H, closed to the left, the usual 65-cycle, 86⅔-cycle signal is impressed on the TL antenna system, giving the synchronized figure-of-eight transmission characteristic for giving the four courses. However, whenever relay G closes, say to the left, and relay, H, closes to the right, a 1-dot cardioid signal will be sent in the direction of point S and no signal in the direction of point V. When relay G closes to the right and H closes to the right, a 2-dot cardioid signal will be sent in the direction of point V and no signal in the direction of point S.

The method of obtaining the cardioid transmission is illustrated in figure 13. In this figure, for the sake of simplicity, the split hybrid coil is not shown. AM represents the current in antenna L supplied from point Z, and AP the current from point Y. AC represents the current in antenna K supplied from point Z, and AT the current from point Y.

Figure 13 (a) shows the vector relations of the currents in the two antennas without reversal of coupling at X and I. Here the net result of the signal impressed at Y is zero.

Figure 13 (b) shows the effect of reversing the coupling at I. This 180° change produces a current AT 180° out of phase with AC and a current AP in phase with AM, leaving AC and AM unchanged.

Figure 13 (c) shows the effect of reversing the coupling at X. This rotates AT and AC 180°, leaving AM and AP unchanged.

Figure 13 (d) shows the effect of adding the 90° phasing section J, causing a 90° lag in both AT and AP.

Figure 13 (e) shows at AC' and AT' an additional lag of 21° in both AC and AT when considering the signal as received in line with the two antennas at some point V. This 21° is the space phase due to the physical separation of antennas *L* and *K*. The vector sum of *AM* and *AC′* is *AQ*, and the vector sum of *AP* and *AT′* is *AR*. As *AR* can be made equal in intensity to *AQ* by means of a clip connection on inductance *W* (fig. 12) and is 180° out of phase with *AQ*, no signal will be received at point *V*.

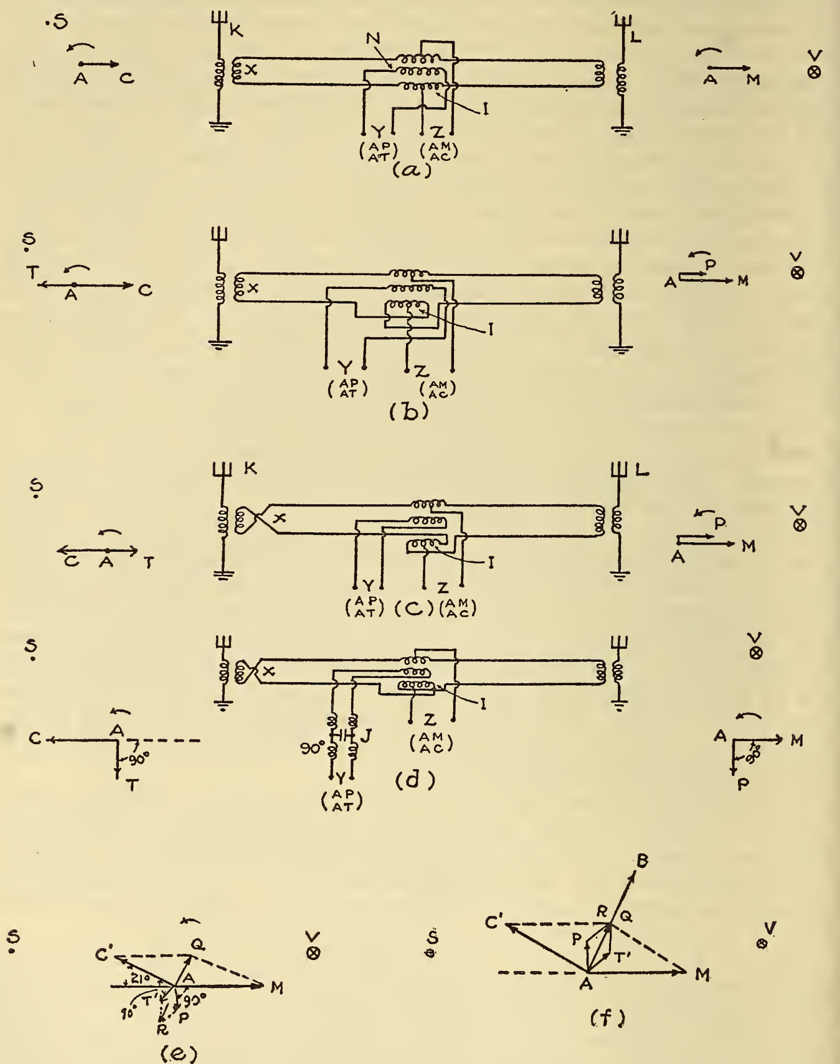

FIGURE 13.—*Method of obtaining cardioid transmission by combining figure-of-eight radiation with two nondirectional in-phase radiations from the two antennas.*

Figure 13 (*f*) shows the effect of reversing the currents supplied at *Y* by means of reversing relay *G*. The phase of *AP* and *AT′* are both changed by 180° and the resultant *AR* will be in phase with *AQ* and a signal of double the intensity *AB* will be received at point *V*. This corresponds to the signal received at *S* corresponding to the conditions of fig. 13 (*e*).

VI. APPLICATION OF THE IDENTIFICATION SIGNALS TO THE ESTABLISHED AIRWAY RADIO RANGE SYSTEM

This system of course and quadrant identification is easily applied to existing beacon stations of either the visual or aural types using the TL antenna system, as it requires no alterations to the antenna structure but merely adds relays and phasing sections in the transmission lines inside the beacon station house. A motor-driven code wheel is also required in the case of the visual beacon and a code wheel geared to the motor operating the interlocking A–N switch in the case of the aural beacon.

There are three methods of applying the cardioid transmissions to fit in with the established airways:

(1) The simple cases where the TL antennas are laid out along the four cardinal points of the compass, as has already been described, in which case the 1 dot is always sent west, 2 dots east, 3 dots north, and 4 dots south, as in figures 3 and 10.

(2) Cases where the TL antennas are laid out without any relation to the four cardinal points of the compass. There are two alternative methods under this heading:

(*a*) Either to transmit the cardioid signals from both TL antenna systems simultaneously such that the resultant cardioids will be in directions corresponding to the four cardinal points of the compass, resulting in cardioid signals as in case 1, or:

(*b*) To transmit the cardioid signals in the direction of the TL antennas and to provide the pilot with a set of rules and a map showing the direction of transmission of the cardioid signals for each beacon.

Of the two cases, (*a*) and (*b*), the latter seems somewhat preferable, as the simultaneous transmission of two cardioids required in case (*a*) complicates the radio-transmitting equipment somewhat.

Considering case (*b*), therefore, where the cardioid signals are sent in 4 different directions not coinciding with the 4 cardinal points of the compass, it is only necessary to illustrate the direction of transmission of the coded identification signal on the pilot's chart of each beacon, which he always has at hand, to give him all the necessary information. Such a chart illustrating the application to three radio beacons designated as *A*, *B*, and *C*, respectively, is shown in figure 14. Here the nos. 1, 2, 3, and 4 indicate the sectors where the dot signal of that number is heard with the maximum intensity. The small round dots represent the layout of the four antennas, differently located with respect to the points of the compass in each case. Thus, assume a pilot to be lost. From the beacon identification letter, which, let us say, is D (— ..), he finds he is receiving the "*B*" radio range. He also finds from his beacon course signal that he is in a 65-cycle or *A* (. —) quadrant. When the 1- and 2-dot quadrant and course cardioid identification is heard (see fig. 14 at (*a*)), the 1- and 2-dot signals are somewhere near equal in intensity, thus placing the pilot in region *FG* or *HI* and confirming the indication given by the beacon course signal that the pilot is in a 65-cycle or *A* (. —) quadrant. When the 3- and 4-dot signals are heard, (see fig. 14 at (*b*)), the 3 dots are barely audible, while the 4 dots are very loud. This immediately places the pilot definitely southeast of the "B" beacon in region *FG*.

Even though the beacon may have bent courses as shown, the identification method holds good, since a different combination of strong and weak signals will always be received on each different course and quadrant.

In a few special cases where the four courses are aligned approximately along the lines of direction to the TL antennas, it is necessary to send only the two cardioid signals, the dot and 2 dots. With but two identification signals, there are two opposite courses shown at *A*, figure 8, along the line to antennas 26 and 28, along which there is no differentiation in the identification signal, the dot and 2 dots being about equal in intensity on each course. However, the pilot can

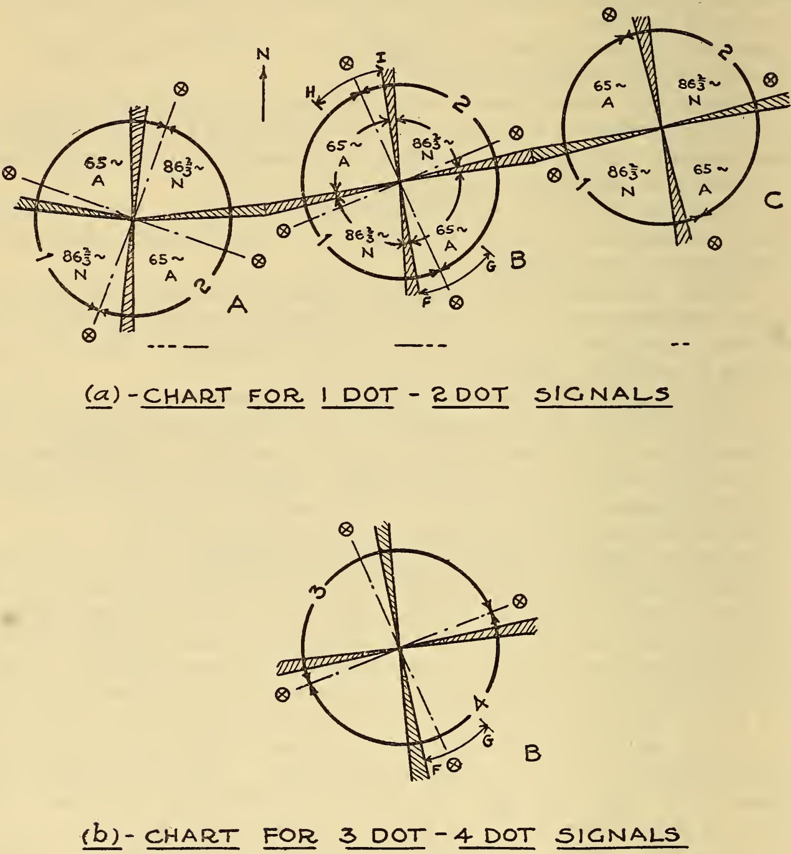

FIGURE 14.—*A chart as might be furnished to pilots using the quadrant and course identification signals.*

determine which of the two courses he is on by deviating to the right and noting which off-course signal predominates. Thus, if his compass shows he is flying north and he obtained an increase in the *N* or 86⅔-cycle signal when deviating to the right, he is on the course extending south of the beacon, because if he had been flying north and deviated to the right and obtained an increase in the A or 65-cycle signal, he would have been on the course north of the beacon.

A simple set of rules which might be followed in all cases, having given the location of the four antennas with respect to the points of the compass, would be:

(1) When the antenna system is laid out such that the lines of direction between diagonally opposite antennas coincide with the 4 cardinal points of the compass, then the 1-dot signal shall be sent in a westerly direction, 2 dots east, 3 dots north, and 4 dots south.

(2) When the antenna system is laid out such that lines between diagonally opposite antennas do not coincide with the four cardinal points of the compass, then the 1-dot signal will be sent in a westerly direction along the line of direction of the two diagonally opposite antennas extending the most nearly east and west. In the special case where the antenna system is laid out such that the lines between diagonally opposite antennas are at an angle of 45° with respect to the four cardinal points of the compass, then the 1-dot signal shall be sent in the northwest direction.

(3) The 2-, 3-, and 4-dot signals shall be sent in directions corresponding to the following degrees of azimuth going clockwise around the beacon from the direction in which the 1-dot signal is sent—2 dots, 180°; 3 dots, 90°; 4 dots, 270°; and in the order—1 dot-2 dots, then 3 dots-4 dots.

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