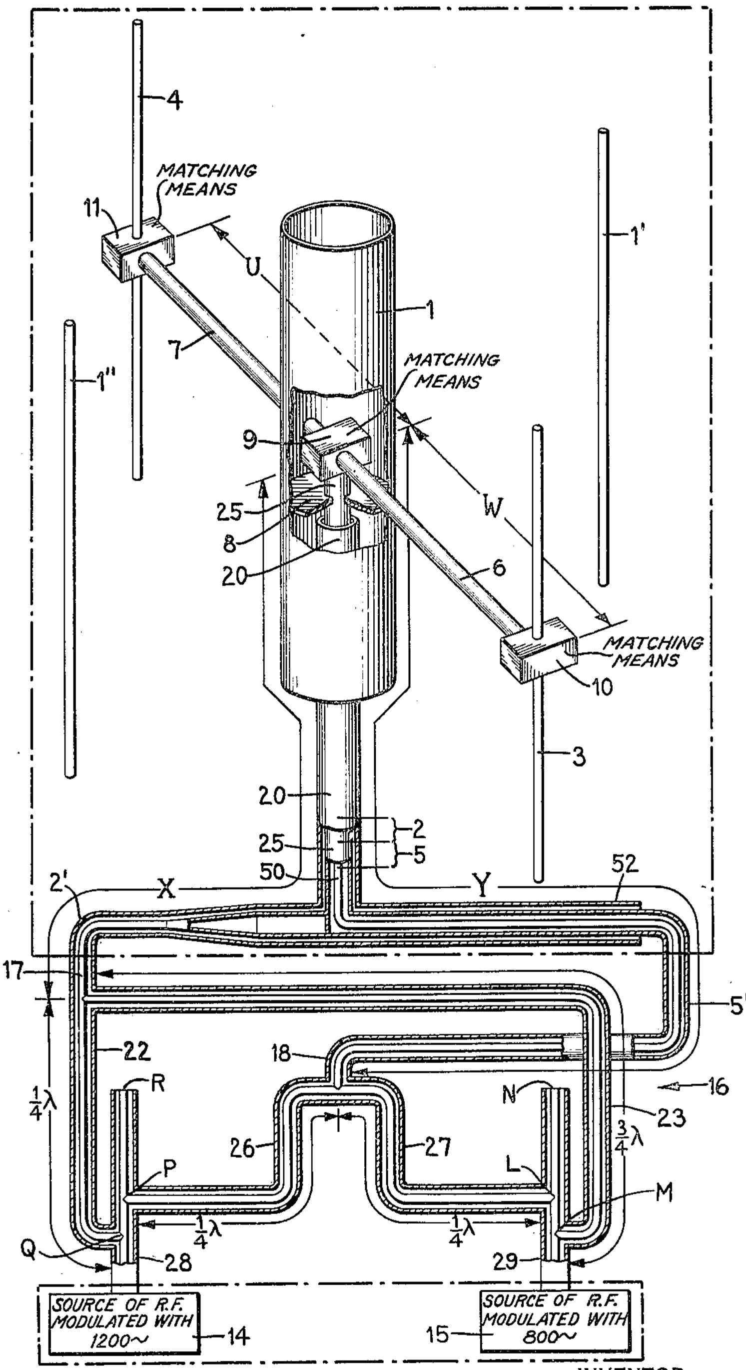
Aug. 12, 1941. J. GOLDMANN 2,251,997

DIRECTIONAL RADIO SYSTEM

Filed Oct. 22, 1938 3 Sheets-Sheet 1

FIG.1.



INVENTOR
JOACHIM GOLDMANN

BY [signature]
ATTORNEY

FIG.1A.

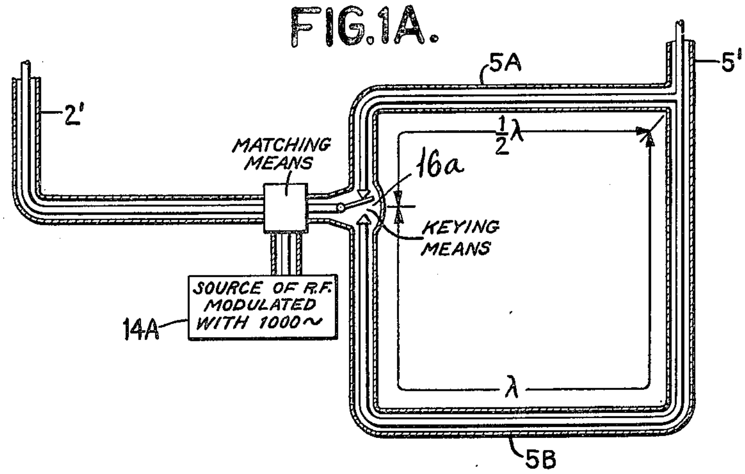
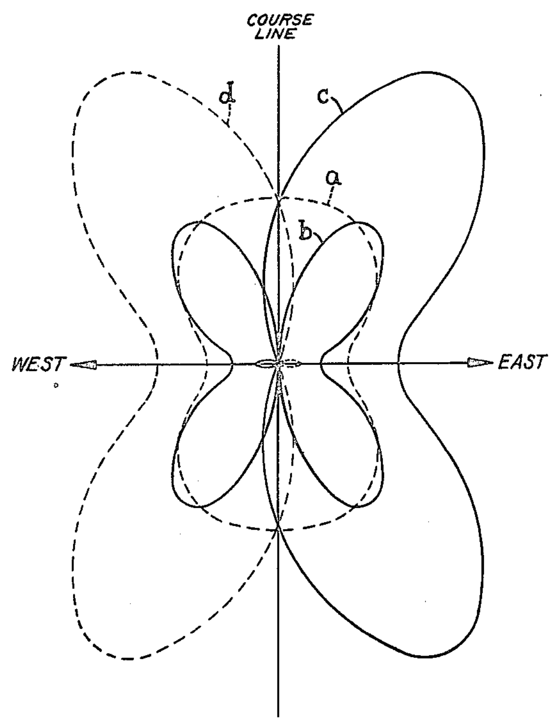


FIG.2.



INVENTOR
JOACHIM GOLDMANN
BY [signature]
ATTORNEY

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Filed Oct. 22, 1938 3 Sheets-Sheet 3

FIG.3.

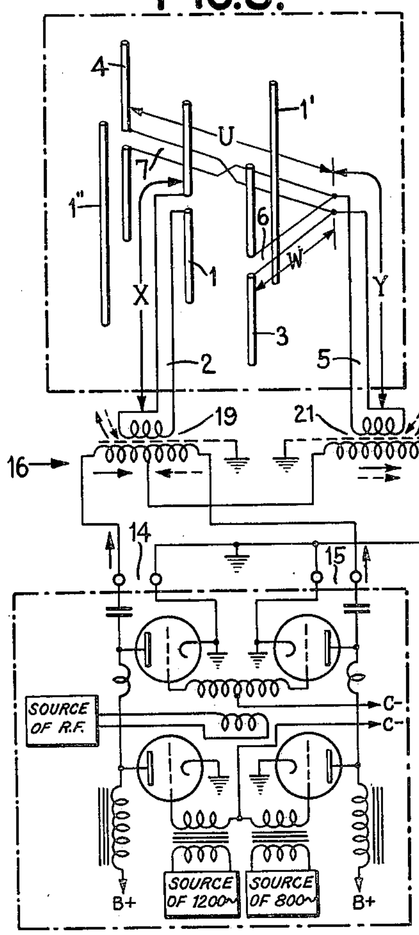


FIG.4.

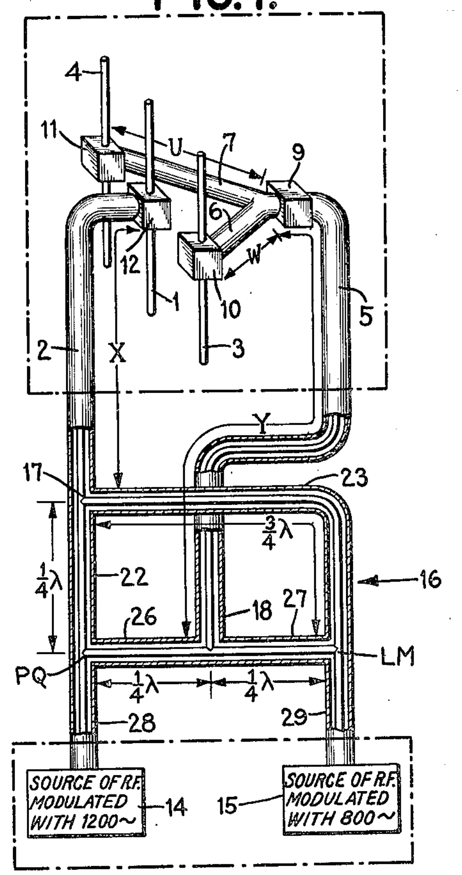
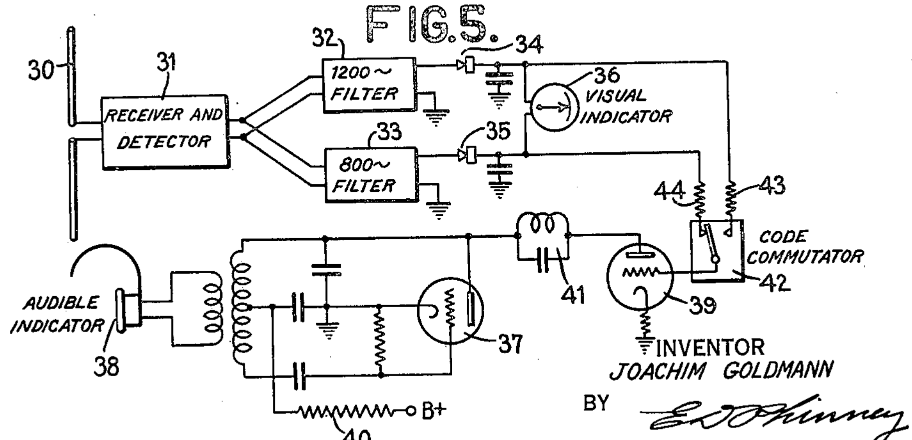


FIG.5.



INVENTOR
JOACHIM GOLDMANN
BY E. D. Phinney
ATTORNEY

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UNITED STATES PATENT OFFICE

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DIRECTIONAL RADIO SYSTEM

Joachim Goldmann, Berlin-Wilmersdorf, Germany, assignor to International Telephone Development Co., Inc., New York, N. Y., a corporation of Delaware

Application October 22, 1938, Serial No. 236,453

11 Claims. (Cl. 250—11)

The present invention relates to directional radio systems and particularly to directional radiating systems suitable for use as course indicating beacons.

It is an object of my invention to provide a directional array whose pattern is more sharply directed in the vicinity of the course line for a given radiation power than arrays heretofore known.

Another object of my invention is to provide a radio system wherein a transmission network feeds an antenna array comprising two separate antenna means, so as to produce two differently directed radiant action patterns each having a distinctive signal and each corresponding to energization of both the antenna means of the array.

A further object of the invention is to provide an improved lead-in construction.

In accordance with one feature of the present invention, two symmetric antenna means are combined into a directional array for producing two differently directed radiation patterns. In the simplest case one means consists of a single dipole and the other consists of two dipoles. Both antenna means are energized for each of the patterns, but the phase relation between the energization of the two antenna means is different for the two radiation patterns. According to a further feature of the invention, one of the antenna means comprises an even number of dipoles preferably symmetrically disposed about the course line but energized asymmetrically. The other antenna means comprises one or more antenna elements symmetrically disposed with respect to the course line and also symmetrically energized. The combination of these two patterns results in a first pattern of unsymmetric shape with respect to the course line. If the phase of the physically symmetrical but phasally asymmetric means are reversed with respect to the phase of the truly symmetrical means, a second differently directed radiation pattern results which is the mirror image of the first pattern. These two patterns are used to define a line of equal intensity which is the desired course line.

According to another feature of the present invention, a directional antenna array comprising two separate antenna means preferably conjugate to each other at their input terminals, is energized over a network from two signal sources in such a way that the waves from one signal source are applied to both antenna means in one phase relationship and the waves of the other signal source are applied also to both antenna means but in the opposite phase relationship.

According to a further feature of the present invention, similar antenna arrays and networks are conversely used for a directional receiving system giving an action essentially the reverse of the action produced when used as a radiation system.

The nature of the invention may best be understood by reference to the attached sheet of drawings, in which

Fig. 1 represents, partially in perspective and partially in schematic diagram, a preferred type of radiation system in accordance with the invention, embodying also a preferred type of antenna array in accordance with the invention;

Fig. 1A illustrates a keying arrangement for use in certain embodiments of my invention.

Fig. 2 is a polar diagram of the radiation amplitude of the system of Fig. 1;

Figs. 3 and 4 represent, partially in perspective and partially in schematic diagram, alternative forms of systems in accordance with the invention;

Fig. 5 schematically represents a receiver for use with any of the transmitting systems of Figs. 1, 3 or 4.

Referring more particularly to Fig. 1, a central dipole 1 is fed over a lead-in line 2 from a supply system more particularly described hereinafter. Side dipoles 3 and 4 are symmetrically arranged about dipole 1 along a line perpendicular to the desired course line, the spacing between 3 and 4 being more than $\frac{5}{8}\lambda$ and less than λ and being preferably 0.92λ, where λ represents a wavelength. These side dipoles are fed over coaxial line 5 and branch lines 6 and 7 from another point of the supply system. The coaxial line 2 which feeds dipole 1 comprises an outer tubular conductor 20 and an inner tubular conductor 25. The coaxial line 5 which feeds the side dipoles 3 and 4 comprises an outer tubular conductor 25 and an inner conductor 50. Thus it will be noted that the tubular conductor 25 serves both as the inner conductor of line 2 and as the outer conductor of line 5, as clearly shown in Fig. 1.

In accordance with the present invention, line 2 is coupled to dipole 1 in a novel manner which simultaneously serves to excite the dipole 1 in a symmetric manner from the line 2, and also to prevent the passage of waves from the lower end of dipole 1 down over the outer conductor of line 2. For this purpose the inner conductor 25 of line 2 is conductively connected to the interior of the hollow dipole 1 near the central point of the latter, by conductive disc 8 which is connected to the interior of the tubular dipole 1 and to the exterior of the inner conductor 25 of line 2, as shown. The outer conductor 20 of line 2 is not galvanically connected to the dipole 1 in any manner, but merely extends up inside of this dipole to a point adjacent the disc 8, as shown. By proper adjustment of the position of disc 8 and the extent to which tubular conductor 20 extends into the dipole 1, the coupling between line 2 and dipole 1 may be adjusted so as to efficiently feed this dipole 1 in substantially matched fashion while at the same time substantially suppressing the flow of waves from the lower end of the dipole 1 down over the outer tubular conductor 20 of the line 2.

For the purpose of feeding side dipoles 3 and 4, line 5 is extended up above the disc 8, and is there connected to branch lines 6 and 7, which in turn extend out through the nodal central point of dipole 1 to the dipoles 3 and 4. Preferably matching means 9 are provided to match the combined surge impedances of branch lines 6 and 7 to the surge impedance of line 5, and matching means 10 and 11 are provided to feed the dipoles 3 and 4 in balanced fashion from the coaxial branch lines 6 and 7, and if necessary to effect a further impedance match at these points. The coupling means 10 and 11 are connected in different manners so that the phase of energization of dipole 3 is opposite to the phase of energization of dipole 4 when these dipoles are excited from the common line 5. Preferably also either the coupling means 9 or the coupling means 10 and 11, or both of these, include sufficient phase delay so that although the physical separation of the side dipoles is about .92λ as mentioned, the electrical length U from dipole 4 through coupling means 11, branch line 7, and half of coupling means 9, to the junction of line 5, and the electrical length W from this junction, through the other half of coupling means 9, branch line 6, and coupling means 10 to the dipole 3, are each equal to an odd number of quarter wavelengths. The effect of this relationship is that with respect to radiations from dipole 1, the side dipoles 3 and 4 each appear to be effectively open circuited at their centers, so as to exert practically no influence as parasitic reflectors upon the radiation pattern of dipole 1 in the absence of excitation from line 5. Even if the electrical lengths U and W are not each made equal to an odd number of quarter wavelengths, these lengths should be made one-half wavelength different from each other, preferably by differences in the connections of the dipoles to coupling means 10 and 11, so that with respect to line 5 dipoles 3 and 4 are oppositely phased, as previously mentioned. This opposed phasing of the two side dipoles with respect to their feed line insures that this feed line 5 will be conjugate with respect to the dipole 1, or in other words insures that as viewed through lines 2 and 5 the dipole 1 and the dipoles 3 and 4 will be conjugate to each other.

Two further dipoles 1′ and 1″ are disposed symmetrically about the central dipole 1 at right angles to the side dipoles 3 and 4, i. e. along the desired course line. These further dipoles are not fed but act as parasitic reflectors. The length of these parasitic dipoles should be approximately one-half wavelength electrically, these dipoles being tuned so that they distort the pattern of dipole 1 to an oblate form having its greatest length along the desired course line. These parasitic dipoles 1′ and 1″ are preferably 0.6 wavelength apart, being each 0.3 wavelength from the central dipole. These parasitic dipoles may be omitted if desired.

In the antenna array shown in Fig. 1, dipole 1, together with parasitic dipoles 1′ and 1″ if these are provided, constitutes what may be called the "truly symmetrical antenna means," and this dipole, or these three dipoles, give a truly symmetrical radiation pattern whose form and phase both are alike on the two sides of the course line. The two side dipoles 3 and 4 constitutes what may be called the "inversely symmetrical antenna means," since these antennae are disposed symmetrically but energized in opposite phase to produce a radiation pattern whose shape is symmetric about the course line but corresponding points of which on the two sides of the course line have opposite phase. The radiation patterns produced by the truly symmetrical and inversely symmetrical antenna means respectively, are shown in Fig. 2, the curve *a* representing the pattern of the truly symmetrical means and the curve *b* that of the inverse means. With a spacing of 0.93λ between the side dipoles 3 and 4 the pattern *b* has four lobes as shown. With spacings greater than 1.0λ this pattern would have more lobes.

In accordance with my invention both antenna means are energized for producing each of the desired resultant radiation patterns, such as patterns *c* or *d* of Fig. 2. For signals which are to be radiated in accordance with radiation pattern *c* of Fig. 2, the excitations of the two antenna means are so phased that at least in the neighborhood of the course line their resulting radiations are substantially cophasal east of the desired course line and in phase opposition west of the desired course line. For signals to be radiated in accordance with the pattern *d* of Fig. 2, the phase relationship between the excitation of the two antenna means is reversed. In order to obtain this phase relationship of the radiant action patterns of the two antenna means, the excitation phases of the dipoles 3 and 4 should differ by 90° from the excitation phase of the dipole 1 if the influence of the parasitic dipoles 1′ and 1″ is neglected. If the parasitic dipoles are so tuned that their reradiating action lags behind the original radiations from dipole 1, this central dipole 1 may be correspondingly excited in a slightly advanced phase so that the total effective phase of the radiant action pattern *a* produced by the dipoles 1, 1′ and 1″ is 90° from the phases of the dipoles 3 and 4.

Various means may be employed for energizing the truly symmetric and the inversely symmetric antennae means in one phase relationship for signals to be radiated in accordance with radiation pattern *c* and in the opposite phase relationship for signals to be radiated with the radiation pattern *d*. If the signals to be radiated are to be distinguished by simple Morse code keying such as the well known A—N keying extensively used at present, a single source of carrier may be used and simple keying means may be employed to reverse the relative phases of excitation of the lines 2′ and 5′ in the rhythm of the A—N code, as shown in Fig. 1A which may be substituted for network 16 and sources 14 and 15 in Fig. 1. Thus during the time intervals belonging to the A code, dipole 1 is excited 90° ahead of dipole 4 and 90° after dipole

3, whereas during the intervals belonging to the N code, dipole 1 is energized 90° ahead of dipole 3 and 90° after dipole 4. In this discussion it is assumed for the sake of simplicity that parasitic dipoles 1′ and 1″ are omitted or that the phase influence thereof is negligible. If a coaxial line system such as that shown in Fig. 1 is employed, the phase reversing means may conveniently be constituted by a relay contact 16A as shown in Fig. 1A which alternately transfers the waves intended for line 5′, over one or the other of two alternate paths 5A and 5B whose lengths differ by 180°. One single modulated or unmodulated source 14A may then serve for giving both signals, the signals of radiation pattern *c* being distinguished from those of radiation pattern *d* by the rhythm of their keying.

In accordance with the preferred embodiment of the invention, however, the two conjugate antenna means 3—4 and 1—1′—1″ are energized from two separate sources of signals distinguished by different carrier frequencies or preerably by different modulation frequencies as indicated in Fig. 1. These two signal sources 14 and 15 feed the lines 2 and 5 through a network 16 which serves to transfer the signals from source 14 cophasally to points 17 and 18 of the network, but which serves to transfer waves from source 15 anti-phasally to these two points of the network. The theory of network 16 may best be understood by first considering the somewhat simpler systems of Figs. 3 and 4.

In Fig. 3 the antenna array itself is schematically represented as an array of dipoles fed by simple open wire lines for the sake of simplicity, but it will be understood that this antenna array may be actually similar to that of Fig. 1. The branch line 6 is physically and electrically of length W. The branch line 7 is physically of the same length as the branch line 6, but is electrically 180° longer because of the transposition shown, the electrical length of this branch line 7 thus being U. As before, U and W differ by 180° and preferably each of these lengths is an odd number of quarter wavelengths. The sources 14 and 15 of Fig. 3 are illustrated as being the output terminals of two separate two-stage modulators, employing plate modulation, and fed by a common radio frequency source to facilitate the problem of maintaining equal amplitudes. The use of a common radio frequency source also results in a fixed phase relationship between the differently modulated outputs of 14 and 15, but this is not essential for the practice of my invention.

The network 16 of Fig. 3 is represented as being a pair of transformers preferably of shielded type connected in the well known hybrid fashion. As shown by the solid and dotted arrows respectively, which represent the current directions in the transformers for a positive surge from source 14 and a positive surge from source 15 respectively, the source 14 energizes the lines 2 and 5 cophasally, whereas the source 15 energizes these lines in phase opposition. The primary of transformer 19 is symmetrically center tapped so that the same magnitudes of excitation are given to the different parts of the antenna array by a given power from source 14 as by the same power from source 15. The stepdown ratio of each transformer is such as to match the impedances of the modulators to the impedances of the lines 2 and 5 which are assumed to be matched to their dipoles. The number of turns on the primary of transformer 21 is for simplicity assumed to be so related to the number of turns on the primary of transformer 19 and to the loads imposed on these two transformers by the lines 3 and 5, that sources 14 and 15 are mutually conjugate. In other words, a voltage from source 14 will produce no voltage across the terminals of source 15 or vice versa. Neglecting phase changes produced by 1′ and 1″ the electrical length X is 90° shorter than the sum of the electrical lengths W and Y, so that in response to waves from source 14 dipole 1 is energized 90° ahead of dipole 3. The system of Fig. 3 is suitable for use with medium or long waves.

In analyzing the network 16 of Fig. 3, it was above pointed out that waves from source 14 produce in all parts of the antenna array the same magnitudes of excitation as would be produced by waves from source 15 but that the phase relation between the excitations of the two antenna means when fed from source 14 is the opposite of the phase relation when fed from source 15. It should also be noted that this relationship may be analyzed in another way which is somewhat more convenient for use with the other networks later to be described. For the purposes of this other analysis, it will be convenient to note at the outset that whether the two generators 14 and 15 are operating with the same or with different frequencies, amplitudes, and/or waveforms, the currents or voltages delivered by these generators may be considered as composed of two pairs of current or voltage components, one pair being of the same waveform, amplitude, frequency and phase in both generators, and the other pair of components being of the same waveform, amplitude, and frequency in both generators but being of opposite phase in the two generators. Then those voltage or current components which are cophasal in these two generators may be designated as signal components S_{co} while those signal components which are in phase opposition in the two generators may be designated as S_{op}. It will then be noted that with respect to signal S_{co} all energy is transferred to line 5, whereas the energy of signal components S_{op} is wholly transmitted to line 2.

Referring now to Fig. 4, the antenna array 1—3—4, though it includes only three dipoles, is of the type having two separate antenna means. One of these means consists of dipole 1, and is truly symmetric; and the other of the means comprises dipoles 3, 4, and is inversely symmetric. Lines 6 and 7 are physically of the same length, but the coupling means 11 couples line 7 to its antenna 4 in the opposite sense from the coupling of line 6 to its antenna 3 by coupling means 10. Thus the electrical length U differs by 180° from the corresponding electrical length W just as in the case of Figs. 1 and 3 previously described. Each of the lengths U and W is again preferably an odd number of quarter wavelengths.

Coupling means 12 serves to feed the dipole 1 in balanced fashion from the unbalanced coaxial line 2, and if necessary also serves to match impedances. This coupling means may be generally similar to coupling means 10 and 11 and may be of any well known type. The electrical length Y plus W, including any phase delays in devices 9 and 10, differs from the electrical length X, including any phase delays in device 12, by 90° or by an odd multiple of 90°. For convenience it will be assumed that X is 90° shorter than Y plus W, so that dipole 1 is excited 90° earlier than dipole 3, and 90° later than dipole 4.

Considering now the network 16, and assuming first that a signal S_{co} is applied cophasally from sources 14 and 15, it will be clear that with respect to this cophasal signal component the arms 22 and 23 of the network have substantially no effect since the arm 22 has a length of ¼λ, and the arm 23 a length of ¾λ, thus making a combined length of one wavelength connected between the points PQ and LM which are assumed to be cophasally energized. Furthermore, it will also be clear that the presence of line 2 connected at junction point 17 to the two arms 22 and 23 will in no way influence the result, since with respect to signals S_{co} the junction point 17 represents a voltage node along the arm 22—23 and thus no finite impedance connected thereto can have any influence. With respect to cophasal components S_{co}, therefore, the network may be considered as comprising solely the arms 28 and 29, the arms 26 and 27, and the line 5 connected between the last mentioned arms at junction point 18. The signal components S_{co} will therefore be wholly fed into line 5. It should furthermore be noted that the length of arms 28 and 29 is immaterial provided it be understood that the components considered as belonging to the signal S_{co} are those components which arrive cophasally at the points PQ and LM rather than the components which leave the generators 14 and 15 cophasally.

With respect to the signal components S_{op} which arrive at points PQ and LM in phase opposition, however, all the energy of these components will be transmitted to the line 2 over arms 22 and 23. The anti-phasal relationship of the signal components at PQ and LM will be changed to a cophasal relationship because of the fact that arm 23 is one-half wavelength longer than arm 22. Furthermore, with respect to these components S_{op} it is clear that the arms 26 and 27 are ineffective because the sum of the length of these arms 26 and 27 is one-half wavelength and because these two arms together form a bridging path between points PQ and LM which are traversed by waves of opposite phase so far as the signal components S_{op} are concerned. The presence of line 5 connected at point 18 between the arms 26 and 27 does not at all alter the relationship because point 18 is at the midpoint of the half wavelength bridging path and thus corresponds to a voltage node, so that it is immaterial what impedances are connected at this point. For the signal components S_{op} therefore, the network may be considered as consisting solely of arms 28 and 29, arms 22 and 23, and line 2 connected to the latter arms at junction point 17.

It will be clear, therefore, that the bridge 16 of Fig. 4 satisfies the condition that the signal components S_{co} arriving cophasally at points PQ and LM are wholly transmitted to line 5 while on the contrary the anti-phasally arriving signal components S_{op} are wholly transmitted to line 2. If the effective input impedances of lines 2 and 5 as viewed from junction points 17 and 18 are alike, the network 16 of Fig. 4 will also satisfy the further condition that the output terminals of generators 14 and 15 will be mutually conjugate, which is in some cases advantageous. The division of power between the two antenna means of the complete antenna array will also be equal in this latter case, so that the signals from each generator will be divided equally between the two antenna means. Such a division of power is in many cases satisfactory.

Referring now to the network 16 of Fig. 1, it will be noted that this network is in many respects similar to the network 16 of Fig. 4. The arm 22 which corresponds to the same arm in the network of Fig. 4 is connected to line 28 at point Q; and the arm 26 which corresponds to the same arm in the network of Fig. 4, is likewise connected to line 28 at junction point P. In the network of Fig. 1, however, the points P and Q do not coincide but are spaced apart, leaving a small section Q—P between these two junction points. A further stub section P—R of line 28 extends beyond junction point P and is short circuited at its free end R. Although Q is shown as closer to the generator 14 than P, the adjustment may be such that the point Q is more remote from the generator than point P. Similarly on the righthand side of the network of Fig. 1, the junction points L and M are separated from each other thus defining an additional line section M—L. The length Q—P should preferably equal the length M—L and similarly the length P—R should equal the length L—N, so that the network will be symmetrical.

Analyzing the network 16 of Fig. 1, in terms of signal components S_{co} and S_{op}, it will be noted that the essential condition that signal S_{co} be wholly transmitted to junction 18 and S_{op} be wholly transmitted to junction 17 is still inherently fulfilled. The input impedances of the network with respect to the two signal components S_{co} and S_{op}, however, may be more or less independently adjusted. With respect to the cophasal component S_{co} arms 22 and 23 may be ignored and the junctions of arms 26 and 27 may be so adjusted along the lines 28 and 29 that the stubs P—R and L—N together with the portions of lines 28 and 29 lying between the generators and P and L respectively, produce any desired impedance transformation as to give any desired impedance at the output of generators 14 and 15 with respect to the cophasal signal components. Similarly with respect to the anti-phasal signal components, the position of junctions Q and M may be adjusted so that the stubs Q—R and M—N together with the sections of lines 28 and 29 lying between the generators and points Q and M, will give the desired impedance transformation for the anti-phasal components.

It is true that the adjustments of impedances for component S_{co} are not wholly independent of the impedance adjustments for component S_{op} in the network shown, since the total length from R to generator 14 is fixed as soon as the length P—R and the length from P to generator 14 is determined. Nevertheless the adjustments shown are sufficient to obtain any desired ratio between the impedances with respect to S_{co} and S_{op}. Thus by properly adjusting the lengths R—P, P—Q and Q—14, as well as the corresponding lengths on the righthand side of the network, the power distribution between the two antenna means may be varied to any desired ratio. At the same time the impedance presented to the generators 14 and 15 by the network may ordinarily be made to assume a convenient value; and exact matching between the generators and the network may be accomplished in the output circuit of the generator. Alternatively, further matching means may be inserted beyond junction 17 or beyond junction 18 in the lines 2′ and 5′ which are individual to the separate antenna means, thus providing completely independent matching adjustments for the cophasal and anti-phasal signals.

The junction points 17 and 18 of the network 16 of Fig. 1 are connected to the lines 2 and 5 by way of lines 2' and 5' as shown. Where the line 5' couples to the line 5 a short-circuited stub 52 of ¼λ electrical length is provided outside of the line 5' so as to avoid short-circuiting the line 2. The line 2' is connected to the line 2 in direct fashion, suitably through a tapered junction if it is desired to maintain line 2' of the same diameter as line 5'.

Although the simplest embodiments of my invention comprise in the truly symmetric means only a single dipole, or in a single dipole with parasitic reflectors, satisfactory results may also be obtained by the use of a plurality of fed dipoles for the truly symmetric antenna means. In fact, a greater number of dipoles than the number shown may be used in either or both of the means provided only that the number of dipoles in the inversely symmetric means should be an even number. In order to obtain a particularly advantageous sharp pattern such as shown in Fig. 2, the inversely symmetric means should in itself produce a pattern having at least four lobes and for this purpose should comprise at least one pair of dipoles spaced more than ⅝λ apart, their separation being preferably at least ¾λ. In accordance with my invention, moreover, this inversely symmetric means preferably comprises at least two dipoles, which may or may not be the same pair just mentioned, whose separation is less than one wavelength. If the dipoles which are spaced more than ⅝λ are more than 1.0λ apart the pattern *b* will have more than four lobes. It is then desirable to further provide another pair of dipoles spaced less than one wavelength apart and fed with sufficient power to shape the radiant action pattern produced by the inversely symmetric means alone so that this pattern has no directions of zero intensity except along the axis of symmetry thus preventing the formation of false courses.

Although the novel method of feeding two antenna means by means of a network such as the network 16 of Figs. 1, 3 or 4, is particularly advantageous in connection with the novel antenna array of my invention, this same general method of feeding may also be employed with certain other types of antenna systems. In particular the feeding system of my invention may be applied to an antenna system consisting of a loop and a centrally disposed dipole, line 2 of Fig. 3 being used for example to feed the loop and line 5 of this figure being used to feed the central dipole. Other antenna arrays having two mutually conjugate antenna means are also suitable for excitation with the novel feeding system of my invention.

It should also be understood that other types of networks than the networks 16 of Figs. 1, 3 and 4 may be employed, for example, a Wheatstone type bridge of resistance or reactance elements may be fed across its conjugate diagonals from sources 14 and 15, and the power across two adjacent arms of this bridge may be applied to the two antenna families. In such a case the bridge arms which feed the antennae may preferably be constituted by the primaries of transformers to the secondaries of which the antennae are connected.

In the preferred embodiment of my invention the sources 14 and 15 supply signals of the same frequency and preferably the same amplitude but modulated with different modulation frequencies, the modulation depth being the same for both signals. Although the antenna arrays above described are symmetric, not only about the course line but also about a line perpendicular thereto, satisfactory patterns may be produced with arrays which are asymmetric about either or both of these lines. Asymmetry about the line perpendicular to the course line is especially desirable when it is desired to define a course extending predominantly in one direction from the array.

Any of the systems above described may, in accordance with my invention, be employed in converse manner as directional receiving systems. In Figs. 1, 3 or 4, for example, sources 14 and 15 may be replaced by separate or partially separate receivers, preferably with means for indicating the relative intensities of signals incoming over lines 28 and 29. Signals from a transmitter on the course line will come in on lines 28 and 29 with equal intensity. Signals from a transmitter not on the course line will come in with different intensities on lines 28 and 29.

If desired, network 16 may be omitted and lines 2 and 5 may be connected to one common receiver through suitable keying means such as described in connection with Fig. 1 for reversing the connections from line 2 (or from line 5) in A—N timing. The use of a network 16 as shown in Figs. 1, 3 or 4, is, however, preferred even when the system is employed for receiving since it obviates the need of moving parts.

In a receiving system also a network such as 16 of Figs. 1, 3 or 4 may be used with certain other types of antenna arrays than the novel type of array provided by my invention. For example, a dipole and a loop symmetric thereto may be connected to junctions 17 and 18 of a network 16 and separate or partially separate receivers may then be connected to lines 28 and 29.

The radiations from my preferred form of beacon comprise two separate radiation patterns such as *c* and *d* of Fig. 2, one of these patterns corresponding to signals modulated with one modulation frequency and the other pattern corresponding to signals modulated with the other modulation frequency. Such signals are well adapted for reception by receivers of the tuned reed type for giving a visual indication.

In case it is desired to receive such frequency modulated signals so as to give an indication of the A—N type similar to that ordinarily given by receivers responding to keyed course beacon transmitters, the special receiving arrangement of Fig. 5 is particularly useful. As shown in this figure a receiving antenna 30 delivers waves to a receiver and detector 31 of known type, the output of this receiver and detector being separated by filters 32 and 33 which are tuned to the modulating frequencies respectively as indicated. The outputs of these separating filters are then rectified by rectifiers 34 and 35 as shown and connected in opposed fashion to a sensitive current or voltage indicating instrument 36 which serves as a visual indicator. If the visual indicator 36 cannot readily be center tapped a shunt may be connected around it, the center point of which is grounded, or the leakage of rectifiers 34 and 35 in a backward direction may be relied upon for completing the circuit of current through the visual indicator.

This equipment will in itself serve as a visual indicating receiving arrangement for use with frequency modulated signals of the type delivered by various transmitter arrangements of Figs. 1, 3 and 4. For the purpose of further providing audible indications of the commonly accepted A—N type, a vacuum tube 37 may be connected up in well known fashion to form an audio frequency oscillation generator as shown, the output of this generator being supplied to an audible indicator 38. A modulating tube 39 whose anode is fed in parallel with the anode of tube 37 through the common impedance 40 is connected as shown to modulate the oscillations of tube 37 by plate modulation in well known manner. Trap circuit 41 is provided to prevent the flow of the oscillation frequency into tube 39. In order to produce the A—N code effect a code commutator or interruptor contact arrangement 42 is provided. This code commutator may be operated by clock work or in any other well known manner, and serves to connect the grid of modulating tube 39 alternately to one side and then to the other side of visual indicator 36 with a coded timing corresponding to the Morse code for A and N. Thus the grid of modulator 39 is connected to the lower side of indicator 36 during intervals corresponding to the Morse code letter A and is connected to the upper side of indicator 36 during the intervals corresponding to the Morse code letter N, these intervals being intermeshed in well known manner so that at all times the grid of modulator 39 is connected to one or the other side of the indicator. In order to reduce key clicks it may be desirable to make the contact of commutator 42 make-before-break, and in this case resistors 43 and 44 may be provided to prevent short-circuiting of the visual indicator during the transfer of the make-before-break contact arrangement.

The operation of the receiver is as follows: If the signals modulated with one frequency such as 800 cycles are received with the same intensity as the signals modulated with the other frequency, say 1200 cycles per second, the voltages delivered by rectifiers 34 and 35 will be equal and the visual indicator 36 will not be deflected. At the same time the voltages applied to the grid of 39 will remain constant regardless of the movement of commutator 42, and thus the tone produced by generator 37 in the earphones 38 will be of constant intensity, thus simulating the continuous dash signal ordinarily heard on the course line.

If the receiving arrangement is moved to a position where the 1200 cycle modulated signals predominate over the 800 cycle modulated signals, the output of rectifier 34 will exceed that of rectifier 35, and a current will flow downward through the visual indicator 36 suitably deflecting the latter. At the same time the voltage applied to the grid of modulator 39 when the contact arrangement of commutator 42 is in its righthand position will be more positive than the corresponding voltage on the grid when the contact arrangement is in its lefthand position. Modulator 39 will draw more current during the intervals when the contact of the code commutator is in its right-hand position, i. e. during the intervals corresponding to the N code. The voltage supplied to oscillating generator 37 will thus be greater during the intervals when the code commutator is in its lefthand position, i. e. during the intervals corresponding to the Morse code letter A. The audible tone delivered to the earphones 38 will therefore exhibit periodic increases in loudness in accordance with the timing corresponding to the Morse code letter A. Thus a downward current through the indicator 36 and a loudness increase corresponding to the code A in earphone 38 both represent a predominance of signals modulated with 800 cycles per second.

In similar fashion if the signals modulated with 800 cycles per second predominate, an upward current will flow through the visual indicator 36 and the tone in earphones 38 will periodically increase in the timing of the Morse code letter N.

Although I have described and shown certain embodiments of my invention for the purposes of illustration, it will be understood that modifications, adaptations and variations thereof occurring to one skilled in the art may be made without departing from the scope of the invention as defined in the appended claims.

What I claim is:

1. A directional antenna array comprising first antenna means symmetrically disposed with respect to a desired course line, second antenna means comprising an antenna element on each side of said course line, said elements being spaced apart more than ⅝ of a wavelength at the operating frequency, and two translating means separately coupled in like phase relation to said antenna means and in different phase relation to said antenna elements to produce radiant action in accordance with two overlapping patterns.

2. An array according to claim 1, wherein said second antenna means includes at least two elements on opposite sides of said course line and spaced apart less than one wavelength at said operating frequency.

3. A network for transferring high frequency wave energy between two wave translating equipments and two pairs of terminals for cooperative interaction, comprising two lines each an odd number of quarter wavelengths long and differing in length by an odd multiple of a half wavelength, said lines being connected to respectively couple said two equipments to said first pair of terminals, and two other lines each an odd number of quarter wavelengths long and differing in length by an even multiple of a half wave-length, said last mentioned lines being connected to respectively couple said two equipments to said second pair of terminals.

4. A directional radio system comprising wave translating means for translating two separate sets of signal waves, first antenna means symmetrically disposed with respect to a desired course line, second antenna means comprising two antenna elements symmetrically disposed about said line and spaced more than ⅝ of a wavelength apart at the operating frequency, transmission means for coupling both said antenna means with said wave translating means in one phase relationship for one of said sets of signal waves and for coupling both of said antenna means with said translating means in a different phase relationship for said second set of signal waves.

5. System according to claim 4, wherein said wave translating means comprise two separate channels for said separate sets of signal waves, and wherein said transmission means comprises a network coupled to said two channels and having a first pair of points conjugate to said two channels with respect to wave components passing cophasally and equally over said channels, and a second pair of points conjugate to said two channels with respect to wave components passing antiphasally and equally over said channels, said

first antenna means being coupled across said one of said pairs of points and said second antenna means being coupled across the other of said pairs of points.

6. System according to claim 4, wherein said wave translating means comprise one common channel for both said sets of signal waves, and wherein said transmission means comprises keying means for coupling both said first and second antenna means with said common channel in one phase relationship during certain time intervals and coupling both said first and second antenna means with said common channel in a different phase relationship during other time intervals.

7. A directional radio system comprising first and second mutually conjugate antenna means, two wave translating equipments, a network coupled to said equipments, a first pair of points of said network being conjugate to said equipments with respect to wave components passing cophasally and equally through said equipments but in energy transfer relation to said equipments with respect to antiphasal components, and a second pair of points of said network being conjugate to said equipments with respect to wave components passing antiphasally and equally through said equipments but in energy transfer relation to said equipments with respect to cophasal components, connections between one af said pairs of points and said first antenna means, and connections between the other of said pairs of points and said second antenna means.

8. A system according to claim 7, wherein said network coupled to said equipments comprises a first winding having two parts, a second winding, said second winding and one part of said first winding being serially connected across one of said equipments and said second winding, and the other part of said first winding being serially connected across the other of said equipments, and an additional winding coupled to said two parts so as to respond oppositely to currents through said two equipments which traverse said second winding in the same sense.

9. A system according to claim 7, wherein said network coupled to said equipments comprises two lines each an odd number of quarter wavelengths long and differing in length by an odd multiple of a half wavelength, said lines being connected to respectively couple said two equipments to said first pair of points, and two other lines each an odd number of quarter wavelengths long and differing in length by an even multiple of a half wavelength, said last mentioned lines being connected to respectively couple said two equipments to said second pair of points.

10. A beacon for guiding airplanes along a desired path which comprises first antenna means for producing a first pattern of a given frequency shaped with at least four lobes and having oppositely shaped components on the two sides of said path, second antenna means for simultaneously producing a further pattern of said same frequency having like phased components on the two sides of said path, means for deriving one set of signals from said first and second antenna means by coupling said antenna means in one phase relation with respect to one set of signals and deriving energy from said first and second antenna means by coupling said antenna means in a different phase relation with respect to another set of signals, and means for comparing said derived energies.

11. A beacon for guiding airplanes along a desired path which comprises first antenna means for producing a first pattern of a given frequency shaped with at least four lobes and having oppositely shaped components on the two sides of said path, second antenna means for simultaneously producing a further pattern of said same frequency having like phased components on the two sides of said path, and means for energizing said first and second antenna means in one phase relation with one set of signals and energizing said first and second antenna means in a different phase relation with another set of signals.

JOACHIM GOLDMANN.