June 22, 1954 A. ALFORD 2,682,050

LOCALIZER ANTENNA SYSTEM

Filed Feb. 5, 1951 3 Sheets-Sheet 1

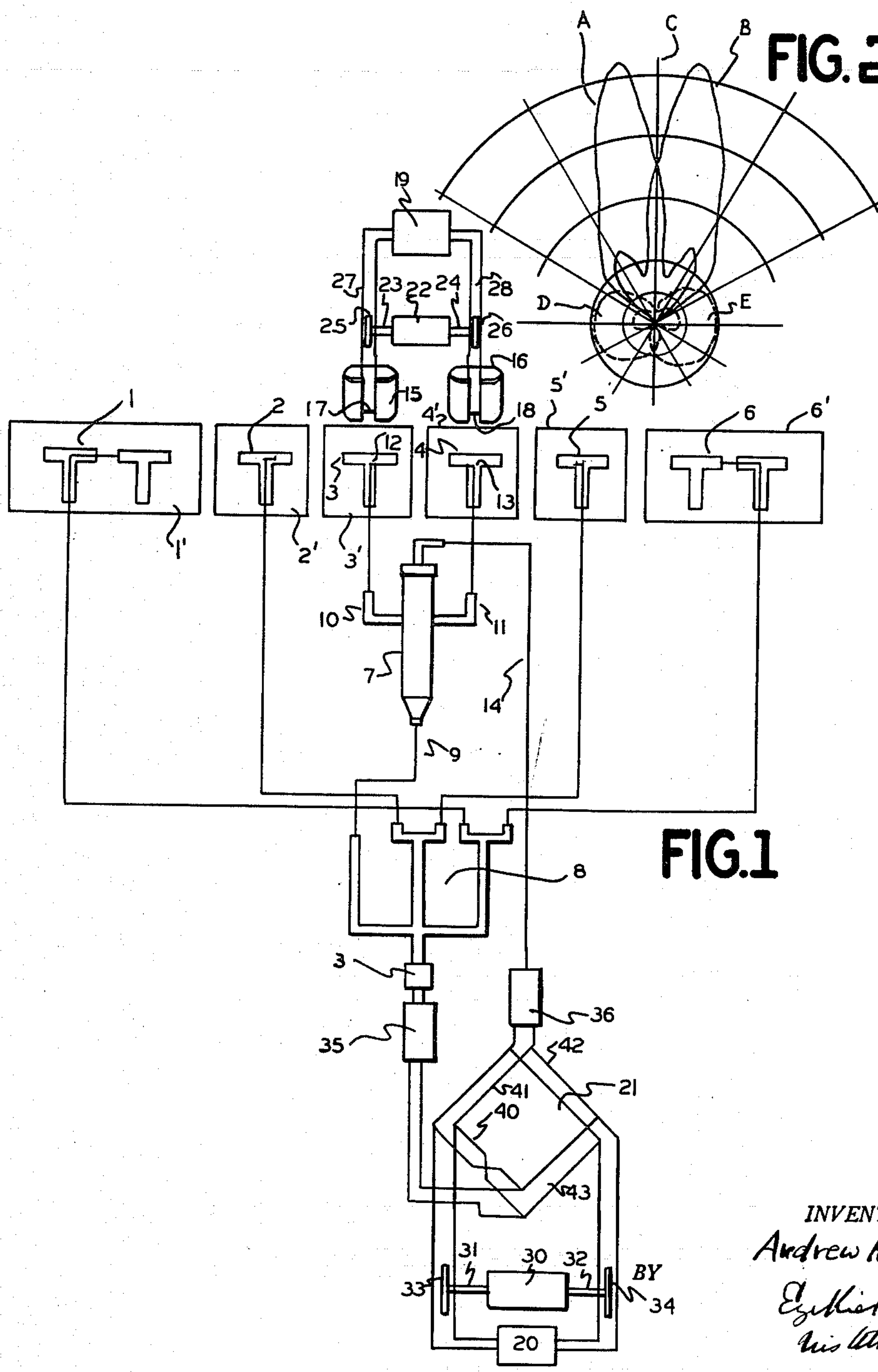


FIG. 2

FIG.1

INVENTOR.
Andrew Alford
BY
Ezekiel Wolf
his Attorney

June 22, 1954 A. ALFORD 2,682,050

LOCALIZER ANTENNA SYSTEM

Filed Feb. 5, 1951 3 Sheets-Sheet 2

FIG. 3

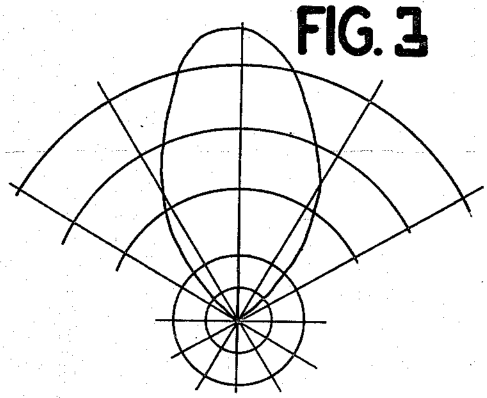


FIG. 4

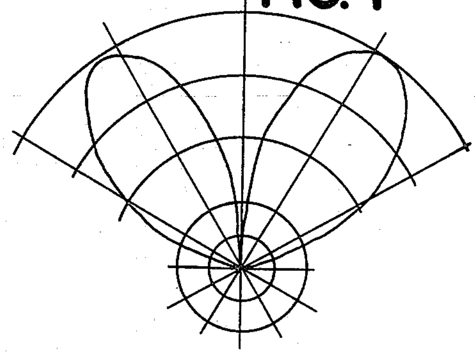


FIG. 5

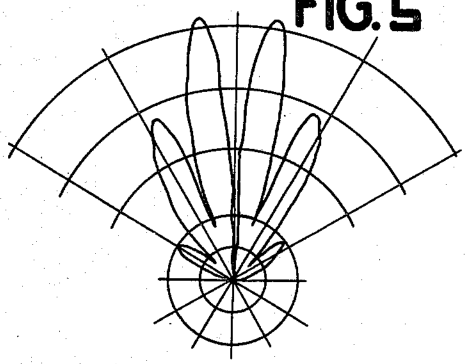


FIG. 6

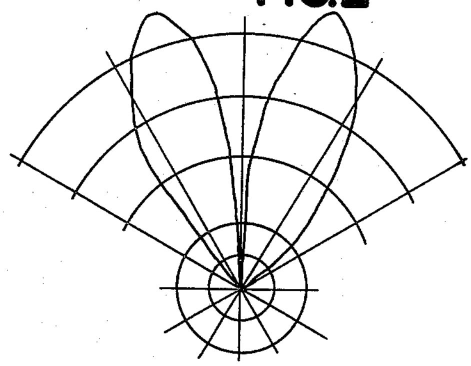


FIG. 7

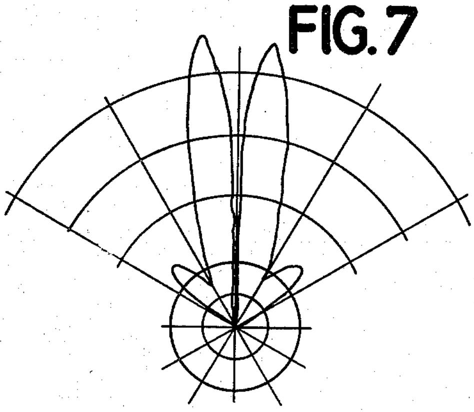
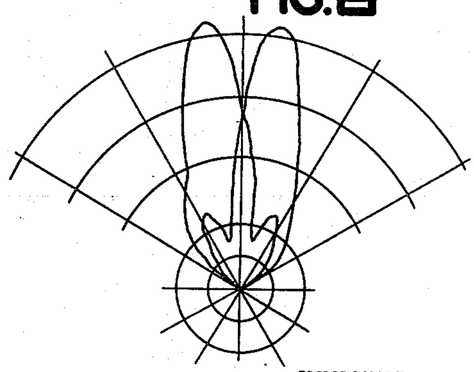


FIG. 8



INVENTOR.
Andrew Alford

BY Ezekiel Wolf
his Attorney

June 22, 1954 A. ALFORD 2,682,050

LOCALIZER ANTENNA SYSTEM

Filed Feb. 5, 1951 3 Sheets-Sheet 3

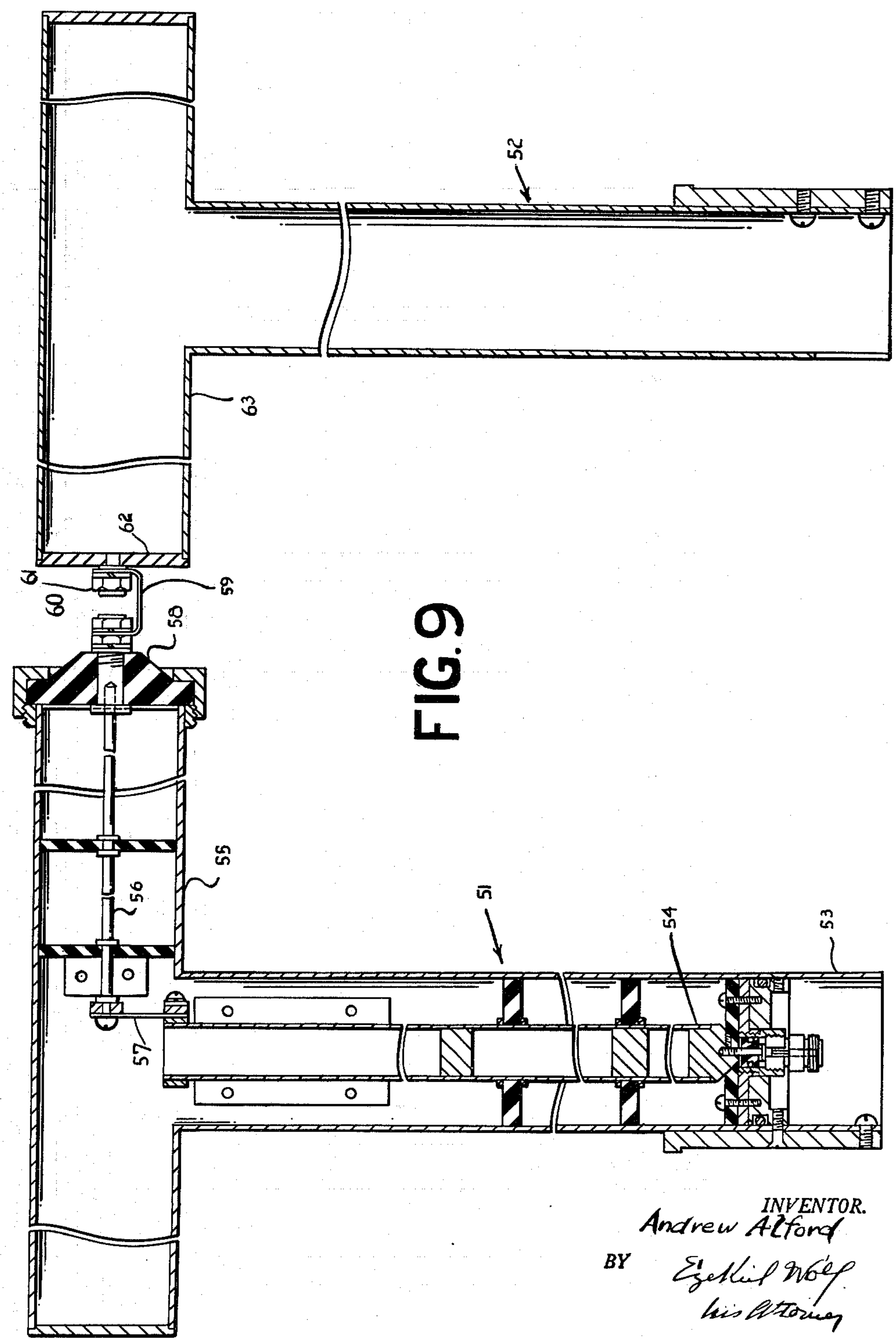


FIG. 9

INVENTOR.
Andrew Alford
BY Ezekiel Wolf
his Attorney

Patented June 22, 1954

2,682,050

UNITED STATES PATENT OFFICE

2,682,050

LOCALIZER ANTENNA SYSTEM

Andrew Alford, Cambridge, Mass.

Application February 5, 1951, Serial No. 209,431

13 Claims. (Cl. 343—107)

The present invention relates to a combination antenna array and more particularly to a localizer antenna system. In the present invention, the antenna system comprises two arrays, a main array and a subsidiary array. The main array is intended to produce the principal localizer course as for instance along a landing runway for an aircraft. The subsidiary array essentially provides the back course but both of these elements cooperate with one another to effect and establish a complete localizer system.

Both arrays are essentially unidirectional, although the subsidiary array which provides the back course sends out a substantial signal at right angles to the course. When both arrays are operating, there is a signal in all directions so that the aircraft approaching from a distance in any direction will be able to pick this signal up and use it as a landing guide. The subsidiary array is energized with a carrier frequency which is between 5 and 20 kilocycles higher or lower than the frequency of the carrier used to energize the main array. But the same modulation is used on both arrays so that the signals received by the aircraft receiver after demodulation are identical whether they come from the main array or the subsidiary array and in fact the listener or observer will not know whether the main or the subsidiary array is responsible for the signal. For instance, if the main array has a carrier frequency of 110 megacycles and the subsidiary array is energized 5 to 20 kilocycles higher or lower than that frequency then the frequency of the subsidiary array would be 110.005 to 110.020 megacycles or 109.080 to 109.995 megacycles. The modulating frequency will be an audio frequency of perhaps 90 cycles for the right antenna of the system and 150 cycles for the left antenna of the system.

The fact that the carrier utilized in the two arrays are of different frequencies results in two benefits. (A) The interference in the overlapped region between the patterns of the main and of the subsidiary array is avoided. (B) Reflections from objects in the field of the subsidiary array cannot produce an interference pattern along the main course, so that sharp bends in the main course resulting from objects outside the radiation pattern of the main array are avoided. To take full advantage of this arrangement, it is desirable that the main array be designated in such a way that its overall radiation pattern would occupy as narrow a section as possible. The narrower this sector is, the less chance there is that there will be a hangar, telephone wires, or

other reflecting objects which could produce an interference pattern and, therefore bend along the main course.

The present invention does not relate to the receiving circuits other than the antenna system nor to methods of providing indications and any suitable standard arrangement which are now known and employed may be used for this system.

It will be seen from the specification as set forth below that the main array comprises preferably two narrow beams producing a left beam and a right beam which will be energized with the same audio frequency modulation corresponding to the left and right lobe of the subsidiary array so that a resultant composite signal may be received in the receivers on the aircraft and may be used to produce an indication on a meter showing that the aircraft is on the right side of the beam, the left side of the beam, or right on the beam. The virtue of this combination is that no matter in what direction the aircraft is approaching the landing strip and no matter where the aircraft is, as long as it is within the range of the subsidiary array, that a positive and definite indication will be given to the aircraft. Without this combination, it is possible for the aircraft to miss the beam entirely, particularly if the beam is very narrow, since the aircraft may pass through the beam before the observer has an opportunity to notice that he is in the beam.

Without further describing the merits and advantages of the present invention, the invention will be described in connection with the drawings illustrating an embodiment thereof in which:

Figure 1 shows somewhat schematically a general layout of the whole system.

Figure 2 shows a localizer radiation pattern of the main and subsidiary array.

Figure 3 represents a so-called "dumbbell" pattern.

Figure 4 represents a calculated "cloverleaf" pattern of the radiation of the same antennas used in producing the pattern of Figure 3.

Figure 5 represents a calculated pattern of the radiation of the outer elements of the array of Figure 1.

Figure 6 represents a calculated pattern of the radiation of the central pair and the next adjacent pair of antennas of Figure 1.

Figure 7 represents a calculated total "cloverleaf" pattern of the radiation of the array of Figure 1.

Figure 8 represents a calculated localizer pattern combining both "cloverleaf" and "dumb-bell" patterns of the array of Figure 1; and

Figure 9 shows a full wave dipole which may be used as the end array element of the structure of Figure 1.

In the arrangement shown in Figure 1, the main array comprises elements 1, 2, 3, 4, 5, and 6 arranged in a straight line at right angles to the projected course with each element being used for producing both left and right beams of the type illustrated in the composite pattern of Figure 8. Antenna elements 3 and 4 are each approximately half wave dipole and so also elements 2 and 5; elements 3 and 4 forming one pair and elements 2 and 5 forming a second pair. Elements 1 and 6 are one wavelength long and may be constructed as shown in the structure of Figure 9. Each of the elements may be provided with corresponding reflectors 1', 2', 3', 4', 5', and 6' with the antenna units all on the same side of the reflectors. The central pair of units 3 and 4 are fed by a coaxial bridge 7 which preferably is of a type described in my application, Serial No. 175,694, filed July 25, 1950. The units 2 and 5 are fed in opposite phase through a transformer 8. The full wavelength antennas 1 and 6 are also fed through the transformer 8 in opposite phase and the coaxial bridge 7 is also fed from the transformer by means of the transmission line 9. It will be noted in the arrangement of Figure 1 that the antennas 1, 2 and 3 are energized in the same phase and 4, 5 and 6 are also energized in the same phase which is opposite, however, to the phase of energization of the antennas 1, 2 and 3 so that on each half of the course the antennas are fed in the same phase but opposite to the antennas on the other half of the course. This applies to the so-called "cloverleaf" energization of the antennas. The transmission line 9 which impresses its energy into the coaxial bridge at its lower end has a balanced output by means of this feed through the arms 10 and 11 which are in the same phase so that the feed from the arms 10 and 11 to the antennas 3 and 4 respectively are connected in reverse phase as indicated by the connecting elements 12 and 13 respectively. The construction of the coaxial bridge of the applicant as shown in his copending application also indicates that when the coaxial bridge 7 is fed by the transmission line 14 into the top end of the coaxial bridge, the outputs in the arms 10 and 11 are in opposite phase so that by effecting connections 12 and 13 as shown the result is that the energy fed by means of the line 14 will be in phase in the antenna structures 3 and 4. The transmission line feed 14 in the present system has been given the name "dumb-bell" feed while the feed by the transmission line 9 is given the name "cloverleaf" feed. The pattern resulting from the combination of 3 and 4 when the energy is in the same phase results in a single lobe symmetrical with the line of the course, whereas when the energy in the antennas 3 and 4 are in opposite phase, two lobes are provided which together should form a symmetrical pattern with the line of the course.

Figure 3 shows a calculated "dumb-bell" pattern, that is, a pattern obtained by antennas 3 and 4 when fed through the coaxial bridge by means of the transmission line 14 so that antennas 3 and 4 are energized in the same phase.

Figure 4 shows a calculated pattern of radiation of the same antennas 3 and 4 when fed through the coaxial bridge by means of the transmission line 9 and energized in opposite phase.

The calculated patterns for the combination of antennas 2 and 5 which are also fed in opposite phase is somewhat like the arrangement of Figure 4 except that the radiation lobes may be somewhat narrower and two auxiliary lobes are present, symmetrically positioned at a greater angle from the line of the course than the two main lobes.

A calculated pattern of the radiation of elements 1 and 6 when energized in opposite phases is shown in Figure 5. This calculated pattern shows that there are 2 sets of auxiliary lobes on on the outer sides of the pair of main lobes and that in this case the main and auxiliary lobes tend to be narrower than in the case of the combination of elements 2 and 5.

The combined calculated pattern of elements 2, 3, 4 and 5 shown in Figure 6 provides a "cloverleaf" pattern of two lobes symmetrical with the line of the course, each lobe being narrower or more directive than the calculated pattern for the center pair previously described.

The total pattern combining all of the six elements except the in-phase radiation of elements 3 and 4 obtained through the coaxial bridge 7, by energization over the transmission line 14 is shown in Figure 7, the purpose of the combination being to emphasize the main lobes and reduce the auxiliary lobes. The ultimate result which is the combination of energization through the "cloverleaf" and "dumb-bell" patterns is shown in Figure 8 and indicates that the left main lobe and the right main lobe overlap in a symmetrical center region directed along the axis of the course and subtending a comparatively narrow angle. It should be noted that each of the full wave end radiators are considered the equivalent of two half-wave radiators.

This resultant main array produces a different signal on one side of the course from that on the other so that when the aircraft, for instance, or whatever device which may have the listening apparatus is observed, the beam patterns will provide a balance when on course and left or right signals when to the left or right of the course respectively. The means for providing this indication itself may be any of the usual apparatus used for this purpose and does not in itself form a part of the present invention.

The radiation elements 1 to 6 produce the main array. The subsidiary array is produced by the two radiating members 15 and 16 which are also symmetrically positioned with respect to the line of the course. These radiators 15 and 16 may be cylindrical or oval in cross section with air gaps 17 and 18 respectively symmetrically positioned on one side of the shell parallel to the axes thereof. The radiators 15 and 16 comprising the subsidiary array will be energized from a high frequency source 19 whose frequency will be between 5 to 20 kilocycles higher or lower than the frequency of the carrier source 20 used to energize the bridge circuit 21 for the main array. The subsidiary array comprising the radiators 15 and 16 will be modulated preferably by an audio frequency source. This may be accomplished mechanically by the motor 22 provided at each end with shaft extensions 23 and 24 carrying disks 25 and 26 which are provided with uniformly spaced teeth which rotate in a plane between the different sides of the transmission lines 27 and 28. If the disk 25 is provided with three teeth and the disk 26 with five teeth, then the modulation frequency will preserve the same ratio and by rotating the shaft extensions 23 and 24, thirty revolutions per second, the modulation of the radiator 15 will be 90 cycles per second and that of the radiator 16, 150 cycles per second. The motor 22, and the motor 30 for the main array, are driven synchronously or one motor may serve to drive the shafts 23, 23 and 31, 32 so that the disks 33 and 34 which are similar respectively to the disks 25 and 26 will provide the same modulation for the left and right side of the array system. The coaxial transmission bridge 21 changes the phase of energy fed through the branch 40 to be opposite from that fed through the branch 41 so that if the carrier is modulated by 90 cycles by the disk 33, the energy through the branch 40 will come out in opposite phase to that of the energy in the branch 41. The energy through the branches 42 and 43 will, however, be in the same phase and in phase with the energy fed through branch 41. The energy of each outlet of the transmission bridge 21 goes through the baluns 35 and 36 respectively to the transformer 8 and to the transmission line 14 respectively. The baluns are essentially a balancing element used generally in the art, for a description of which reference is had to an article in Very High Frequency Technique, vol. 1, Chapter 3, by Radio Research Laboratory Staff, published by McGraw-Hill, 1947.

Since the power delivered to the "cloverleaf" should be about one-quarter of the power delivered to the "dumb-bell," an adjustable attenuator 37 is provided between the balun 35 and the transformer 8. This attenuator is adjusted to obtain a balance between the "dumb-bell" and "cloverleaf" patterns so that the ultimate pattern produced will be substantially as shown in Figure 8.

Figure 2 which shows a composite pattern of the main and subsidiary arrays is shown as having two main lobes, A and B, the left lobe A lying mostly to the left of the course line C and the lobe B to the right of the course line C. The signal given by the left lobe A will correspond to the modulation of the modulating element 33 which may be 90 cycles per second, while the modulation corresponding to the right lobe B will be 150 cycles per second, because of the modulating element 24. This applies also for the dotted main subsidiary lobes D and E, respectively, the lobe D having a modulating frequency corresponding to the modulating element 25 while the lobe E has a modulating frequency corresponding to the modulating element 26. Along the course line C, the two signals are balanced and, therefore, a balanced indicator may be used to indicate that the pilot is on this course. If the pilot should deviate to the left of the course, the signal from the lobe A will prevail, while if he deviates to the right of the course, the signal on the lobe B will prevail.

The subsidiary array in the present invention is intended to provide a back course in which this array sends out a substantial signal at right angles to the course. This will be evident from the lobes D and E in Figure 2 from which it will be seen that the subsidiary array is intended to cover directions other than those in which two main lobes are situated. Since, however, the modulation of the subsidiary array and the main array lobes correspond, the operator will not realize that he is listening or observing one or the other of these lobes. The subsidiary array is far less strong in the forward direction of the beams A and B than the beams A and B so that the subsidiary array will not be dominant in these sections.

The factors controlling the deviation of the beams from the central course line are first that the radiators on the right and the left side of the center are fed in opposite phases and secondly that while the "dumb-bell" is fed with modulated carriers in additive phase, the "cloverleaf" is fed with one modulated carrier in opposite phase to that of the other modulated carrier through the transformer 8. The resulting pattern, therefore, as explained in Figure 2 is obtained.

The radiators 2, 3, 4 and 5 are preferably balanced slot fed dipoles of half wave length energized through the coaxial transmission lines extending through the stem of the T as indicated diagrammatically in Figure 1.

The end radiators are a full wave length and a full section of the structure for these radiators is shown in Figure 9. This structure is essentially an array of two half wave length elements placed next to each other. The feeding arrangement, however, is simpler than that for a half wave element.

The outer conductors of the two half wave elements consist of two T's 51 and 52 which in section may be cylindrical, oval or other type of section commonly used as a coaxial transmission line. Here the conductor designated as cylindrical is intended to include other types of sections as well. The full wave element is fed through the stem of one T. This comprises the outer conductive cylinder 53 and the inner cylinder 54 forming a coaxial transmission line. The inner cylinder 54 is spaced and insulated from the outer cylinder and is connected at its top to the inner conductor 56 concentrically positioned within the right half of the outer cross bar 55 by the conductive strap 57. The inner conductor 56 is insulated by suitable insulator disks from the outer conductor 55 and connects through insulating end cap 58 to the cap 62 of the cross bar of the outer conductor 63 of the T at the right in Figure 9. A conductive strap 59 makes a good conductive connection from the terminal 60 to the terminal 61 of the conductive cap 62, at the inner end of the cylinder 63 which forms the cross bar for the T 52.

In a construction which I have successfully used, the impedance between the ends of the T's was approximately 650 ohms matched to a 52.5 ohm line by a transformer having a Z_0 of 184 ohms.

The design of the full wave element is such that there are small currents flowing along the stems of both T's. These currents flow in opposite directions in the two stems. At first it was believed that this might result in excessive radiation or perhaps even in minor loads in the direction at right angles to the stems. The only effect of the stem currents is to broaden slightly the radiation pattern.

It will be appreciated that the arrangement of Figure 1 is diagrammatic and that the single lines shown represent transmission lines or wave guides or any other suitable conducting means.

Having now described my invention, I claim:

1. A localizer signaling system for guiding a craft along a course, means for radiating at a main carrier frequency two beam patterns overlapping along the line of the course symmetrically, means for radiating two comparatively broad intersecting lobe patterns slightly off the main carrier having a comparatively lower mag-

nitude of radiation in the direction of the beams than the beam radiations, the beam and the broad lobe radiation on one side of the course having the same modulating frequency and the beam and broad lobe radiations on the other side of the course also having the same modulation frequency but differing from the first modulation frequency.

2. A system as set forth in claim 1 in which the modulating frequencies are in the low audible range.

3. A system as set forth in claim 1 in which the modulating frequency of one group is in the vicinity of 90 cycles and the other in the vicinity of 150 cycles.

4. A system as set forth in claim 1 in which the beam patterns are directed generally slightly to the left and right of the course respectively and the other radiation lobes are mainly to the sides and rear of the beam patterns.

5. A system as set forth in claim 1 in which the broad lobes have a carrier which is in the range from 5 to 20 kilocycles higher or lower than the main carrier.

6. A localizer signaling system for guiding a craft along a course comprising a main array for producing a pair of intersecting lobes one directed to the right and the other to the left of the course and a subsidiary array for producing lobes to the right and left of the course of lower intensity than the beams, means energizing the elements of the arrays to the right of the middle of the array in opposing carrier phase for that of the elements to the left of the middle, means for modulating the carrier of the main array with two different low frequencies in opposing phase and the pair of main array elements adjacent the middle with the two different low frequencies in the same phase.

7. A system as set forth in claim 6 in which the pair of main array elements adjacent the middle are energized with the two different low frequencies in the same phase at approximately four times the power as the energization of the main array elements in opposing phase.

8. In a localizer system of the type described, a main array having a plurality of radiators substantially at right angles to the intended course, a coaxial bridge element energized simultaneously at both ends having opposing side outlets connected to the middle positioned elements of the array, said coaxial bridge element having means for reversing in phase the energy fed to one end from that of the energy fed to the other end and means for feeding the other elements of the array through a transmission line having the same phase as the energy fed to one end of said coaxial bridge.

9. In a localizer system of the type described, a main array having a plurality of radiators substantially at right angles to the intended course, a coaxial bridge element having two input ends and two output ends with means contained therein for reversing the phase of the outputs fed from one input end from that fed from the other input end, feed lines connected from said outputs to the middle positioned array elements, a balanced transmission bridge, a transformer, energizing means for energizing said transmission bridge, a feed line connected from one side of the balanced transmission bridge to one end of said coaxial bridge, a second feed line connecting from the other side of the transmission bridge to the input of said transformer, a further feed line connecting from the output of said transformer to the other input end of said coaxial bridge and still further feed lines connecting from the output of said transformer directly to the other elements of said array.

10. A system as set forth in claim 9 in which the energy fed through the transformer has approximately one fourth of the power as the energy fed directly to the coaxial bridge.

11. A system as set forth in claim 9 in which means are provided between the balanced transmission bridge and the transformer for attenuating the power passing therethrough to approximately one fourth that fed directly from the balanced transmission bridge to the coaxial bridge.

12. A system as set forth in claim 9 in which the means for energizing said transmission bridge includes means for low frequency audio modulation of the carrier wave with two different frequencies each in different feed lines to different sides of the transmission bridge, said transmission bridge having one arm effecting a reversal of phase of power passed therethrough.

13. A localizer signaling system for guiding a craft along a course comprising a group of antennae forming a main array and a group of antennae forming subsidiary array, means energizing individual antennae of said main array to produce "dumb-bell" and "cloverleaf" radiation patterns respectively, and to form together a pair of main composite beams directed to the left and right of the course respectively but overlapping narrowly along the course, means for producing with said subsidiary array radiation patterns of substantially rounded lobes to the right and left of the course and intersecting narrowly on the course of substantially less intensity than the beams of the main array and means for modulating said arrays with different audio frequencies for the right and left lobes respectively whereby the direction of the course may be established.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,212,238	Kolster	Aug. 20, 1940
2,283,677	Kandoian	May 19, 1942
2,321,454	Brown	June 8, 1943
2,402,378	Davies	June 18, 1946