

May 24, 1949.

W. T. REA

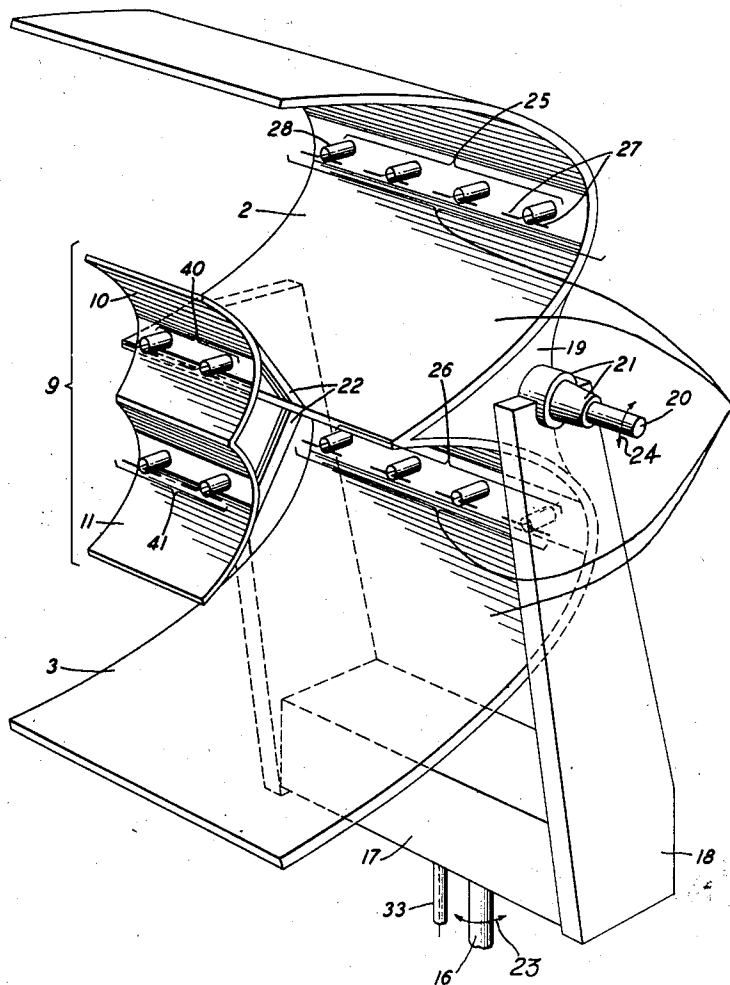
2,471,284

DIRECTIVE ANTENNA SYSTEM

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3 Sheets-Sheet 1

FIG. 1



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2,471,284

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3 Sheets-Sheet 2

FIG. 3

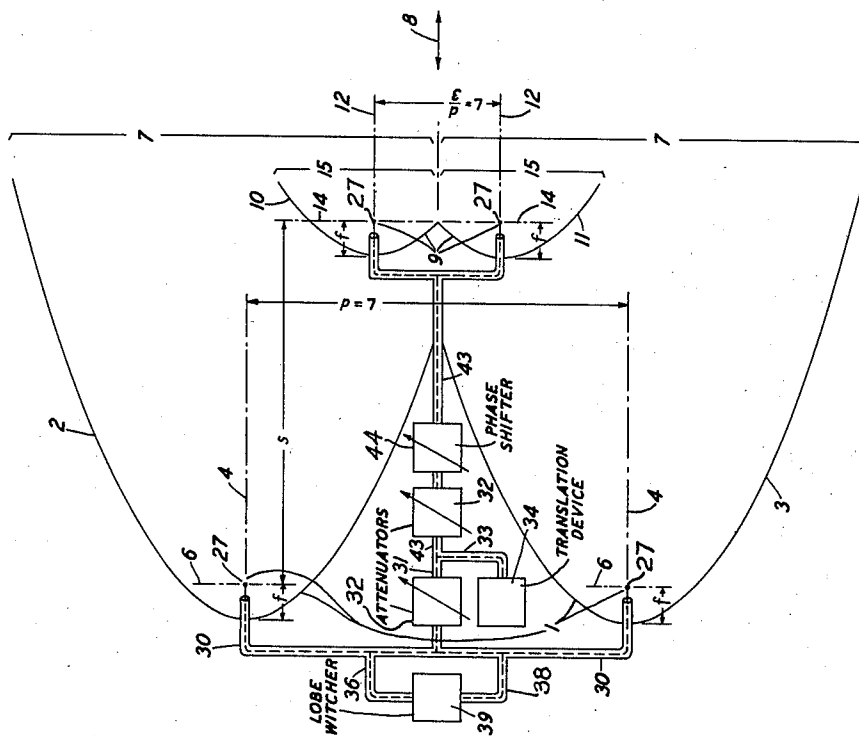
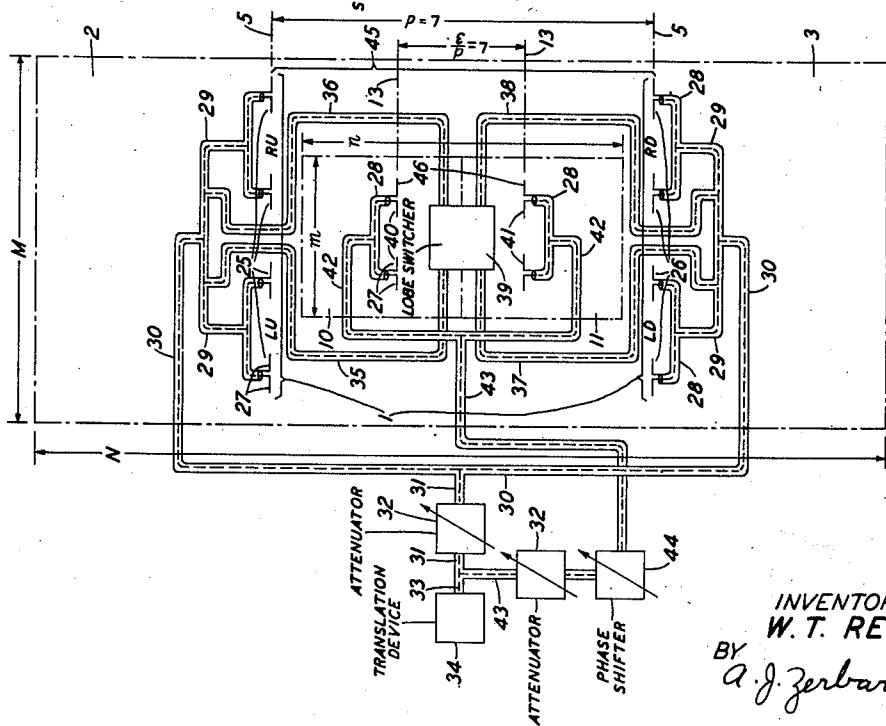


FIG. 2



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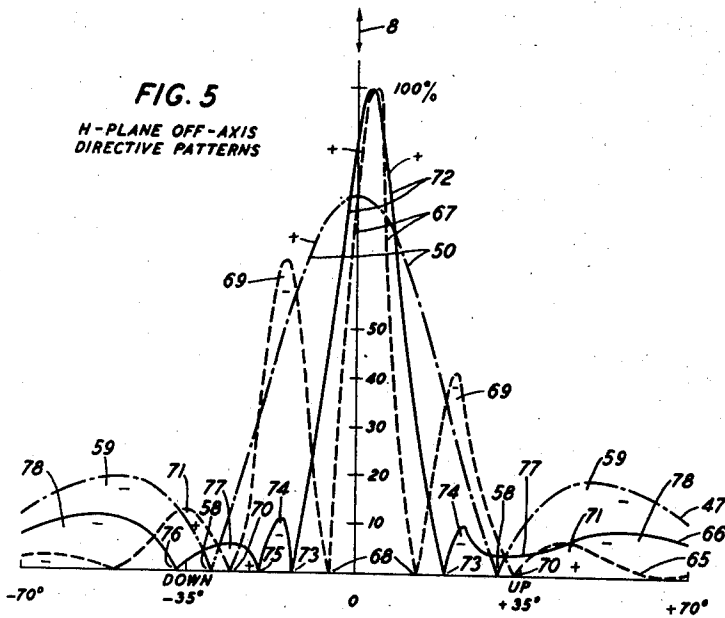
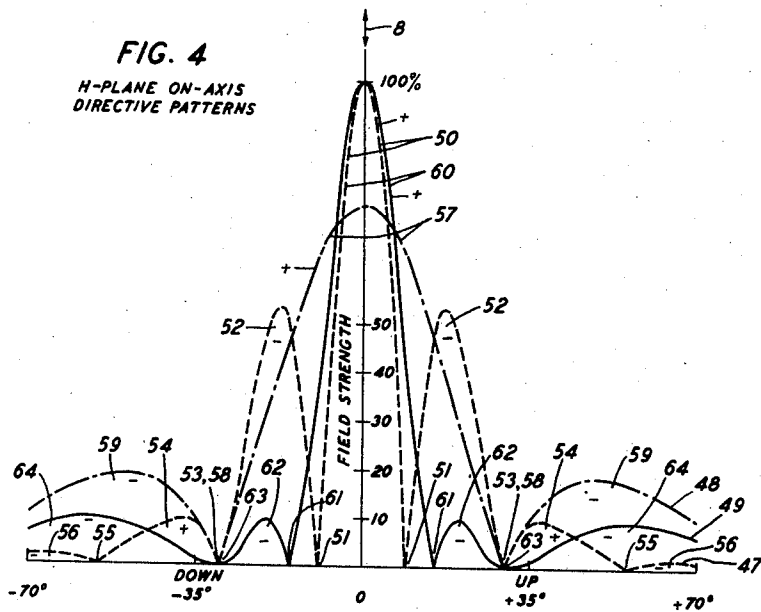
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DIRECTIVE ANTENNA SYSTEM

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3 Sheets-Sheet 3



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2,471,284

DIRECTIVE ANTENNA SYSTEM

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6 Claims. (Cl. 250—33.65)

1

This invention relates to directive antenna systems and particularly to methods and means for reducing minor lobes in the directive characteristics of such systems.

As is known, the first minor lobes in the directive pattern of a search or tracking radar antenna system are highly detrimental since they often produce false indications or false antenna control currents. In particular, assuming that a dual-plane lobe-switching or so-called conical scanning antenna system of the dual-reflector type disclosed in Patent 2,424,982, granted on August 5, 1947, to W. H. Higgins and C. A. Warren, is positioned close to the earth's surface and employed for tracking enemy aircraft, the lower corresponding first minor lobes in the two vertical or H-plane switching patterns are especially detrimental. More specifically, in the system just described, in addition to the desired equi-intensity echo pulses received directly from the target craft on the up and down major lobes of the two switching patterns when the antenna is on-target, undesired unequal pulses may be indirectly received via the reflective earth's surface on the aforesaid lower first minor lobes of the two patterns and, as a result, an incorrect off-target indication may be obtained.

In general, various arrangements have heretofore been proposed for reducing the undesired first minor lobes. In the case of the dual-reflector system referred to above, the use of a small suppressor reflector has been suggested for this purpose, as disclosed in Patent 2,458,885 granted to C. A. Warren on January 11, 1949. While the suppressor reflector system of the copending application just mentioned is now being used successfully for reducing the first minor lobes, particularly in the horizontal or E-plane directive pattern of the main antenna, it now appears desirable to secure a greater minor lobe reduction, especially in the vertical or H-plane pattern, than heretofore accomplished.

It is one object of this invention to secure, in a directive antenna system, a highly satisfactory directive characteristic.

It is another object of this invention to reduce substantially, or eliminate completely, the minor lobes of the directive characteristic of a directive antenna system.

It is another object of this invention, in a directive linear array comprising a pair of spaced antenna elements, to suppress the first minor lobes in the directive pattern of the array, taken in the plane of the array axis, in a more complete manner than heretofore accomplished.

2

It is another object of this invention to eliminate, in a vertical plane lobe switching anti-aircraft radar system located close to the earth's surface, so-called ground reflection effects and the false indications resulting therefrom.

It is another object of this invention to reduce, in a dual-plane lobe-switching antenna system comprising a pair of parabolic reflectors, the first minor lobes in the two perpendicularly related switching planes.

It is another object of this invention completely to eliminate in a directive antenna system utilizing horizontally polarized waves and comprising a pair of vertically spaced cylindrical parabolic reflectors having horizontal focal lines, the first minor lobes in the vertical plane directive pattern.

As used herein the term "parabolic reflector" generically applies to a paraboloidal reflector having a point focus and a cylindrical parabolic reflector having a line focus. The term "directive characteristic" denotes the antenna field or characteristic considered in the solid, that is, in three dimensions; and the term "directive pattern" refers to the trace in a particular plane, such as the H- or E-plane, of the directive characteristic.

For convenience and clarification, the single primary lobe of the main antenna pattern, the single primary lobe of the auxiliary or suppressor antenna pattern and the single primary lobe of the resultant or combined pattern are termed herein the "major" lobe, the "maximum" lobe and the "principal" lobe, respectively; and the secondary lobes of the main, auxiliary and resultant patterns are termed the "minor," the "minimum" and the "subsidiary" lobes, respectively.

In accordance with a simple embodiment of the invention, assuming a main linear broadside array of two spaced antenna elements connected to a translation device such as a radar transceiver, the first minor lobes of the antenna pattern, taken in the plane of the array axis, are eliminated or rendered negligible by means of an auxiliary broadside linear array positioned adjacent the main array and comprising a pair of elements connected to the translation device and spaced along the aforementioned axis a distance equal to one third of the spacing between the main antenna elements. In the transmitting case, the main antenna elements are energized in phase, and the auxiliary antenna elements are also energized in phase, so that the principal axes of the major and maximum lobes are aligned.

Means are provided for rendering these primary

lobes cophasal, and hence for rendering the maximum lobe and the cophasal first minor lobes antiphasal. Also, means are provided for securing a maximum lobe intensity greater than the intensities of the first minor lobes and smaller than the intensity of the major lobe. By reason of the 3-to-1 ratio of the element spacing, the first and second nulls of the auxiliary antenna pattern coincide, respectively, with the second and fifth nulls of the main antenna pattern. The main and auxiliary antenna patterns add algebraically to produce the resultant pattern. The first subsidiary lobes of the resultant pattern have a value about ten per cent of the resultant principal lobe and the remaining secondary lobes of the resultant pattern are insignificant.

In accordance with the preferred embodiment of the invention, a dual-reflector suppressor antenna system comprising a pair of vertically spaced small cylindrical parabolic reflectors, each having a pair of colinear horizontal dipoles aligned with its focal line, is used in place of the single reflector suppressor antenna included in the system of the Warren patent mentioned above. The four dipoles of the suppressor system are connected to the transceiver associated with the main antenna through a single main line for in-phase broadside operation. The effective vertical spacing between the horizontal focal lines of the two small suppressor reflectors, which spacing may differ slightly from the actual or physical spacing, is equal to one-third of the effective spacing between the horizontal focal lines of the two large main reflectors. As in the prior art systems of the two patents identified above, means are associated with the main antenna horizontal dipoles for securing dual-plane lobe-switching. Also, amplitude and phase control means are associated with the main or suppressor system for rendering the intensities of the first minor lobes and the maximum lobe comparable, and the phases of the maximum lobe and the cophasal first minor lobes opposite. As in the simple embodiment, and by virtue of the difference mentioned above between the vertical spacings of the main reflector focal lines and the suppressor reflector focal lines, each of the first nulls of the suppressor H-plane pattern is aligned with a second null of the main antenna H-plane pattern whereby, in both the E- and H-planes and in particular in the H-plane, the minor lobes of the main antenna are almost completely suppressed and the resultant patterns contain only negligible subsidiary lobes.

The invention will be more fully understood from a perusal of the following specification taken in conjunction with the drawing on which like reference characteristics denote elements of similar function and on which:

Fig. 1 is a perspective front view of the preferred embodiment of the invention;

Figs. 2 and 3 are, respectively, front diagrammatic and side diagrammatic views of the embodiment of Fig. 1; and

Figs. 4 and 5 are one-way directive H-plane patterns for the preferred embodiment.

Referring to Figs. 1, 2 and 3 reference numeral 1 denotes a main antenna system comprising an upper cylindrical parabolic reflector or secondary antenna member 2 and a lower cylindrical parabolic reflector 3, each having a horizontal axial plane 4, a horizontal focal line 5, a vertical latus rectum 6, an opening or aperture 7 and a focal distance f of a quarter wavelength. Each aperture 7 is relatively large and approximately

square, so that the ratio of the horizontal dimension M to the vertical dimension N of the main antenna opening is about 1 to 2. The effective vertical spacing between the horizontal focal lines 5 of reflectors 2, 3 is denoted by the reference character L . The axes 8, Fig. 3, are parallel to the on-axis or zero degree transceiving direction 8 which coincides with the equi-intensity direction for the dual-plane lobe-switching system or, stated differently, coincides with the axis of the scanning cone.

Reference numeral 9 denotes an auxiliary antenna system comprising an upper cylindrical reflector 10 and a lower cylindrical reflector 11 positioned symmetrically in front of the main reflectors 2, 3. Each of reflectors 10 and 11 has a horizontal axis 12 parallel to the on-axis direction 8, a focal line 13, a vertical latus rectum 14, an approximately square aperture 15 and a focal distance f of a quarter wavelength. The apertures 15 are equal so so that the ratio

$$\frac{M}{N}$$

Fig. 2, of the horizontal opening to the vertical opening is about 1 to 2. The horizontal distance s between the latus rectums 6 and 14 is more or less critical and, as explained below, the effective vertical spacing of the focal lines 13 of the auxiliary reflectors 10, 11 is about one-third of the vertical spacing between the focal lines 5 of the main reflectors 2, 3.

As shown in Fig. 1, the main and auxiliary antenna systems 1, 9 are supported by a yoke assembly comprising a rotatable vertical shaft 16, a horizontal turntable member 17 attached to shaft 16 and a pair of uprights or vertical arms 18 (only one shown). The two reflectors 2, 3 are secured to a framework comprising member 19 which is associated with a rotatable horizontal shaft 20. Shaft 20 is supported on bearings 21 in arms 18. The auxiliary antenna system 9 is supported by struts 22 attached to the edge portions of the reflectors 2, 3. As indicated by arrows 23 and 24, means (not shown) are provided for rotating the entire assembly in the horizontal plane and for tilting it in the vertical plane.

Reference numerals 25 and 26 denote the primary antennas associated with the upper and lower main reflectors 2, 3, respectively. Each primary antenna comprises four dipoles 27 arranged in a linear array and aligned with the reflector focal line 5 and each linear array 25, 26 comprises two sub-arrays of two colinear dipoles. For convenience, the left upper, right upper, left lower and right lower subarrays are denoted LU, RU, LD and RD, respectively. The two dipoles 27 in each of the four subarrays are connected by two individual coaxial "dipole" lines 28 to a "subarray" coaxial line 29. The upper pair of subarray lines 29 are connected to a coaxial "array" or "reflector" line 30 and the lower pair of subarray lines 29 are connected to another coaxial reflector line 30. The two reflector lines 30 are connected to a main coaxial line 31 which includes an adjustable attenuator 32. Line 31 is connected by the principal coaxial line 33 to a translation device 34, such as a radar transceiver. Numerals 35, 36, 37 and 38 denote "lobing" lines each of which is connected across a different subarray line and is connected to the lobe switcher 39. The lobe switcher may be of the type disclosed in either of the above-mentioned copending applications. Means are included in the lobe switcher for disconnecting the

lobe switcher from the system as explained in the patent to C. A. Warren. The dipole lines 28 have equal lengths; the subarray lines 29 have equal lengths; the array lines 30 have equal lengths, and the lobing lines have equal lengths. As described so far the system is basically the same as the systems disclosed in the above-mentioned patents.

Reference numerals 40 and 41 denote the primary antennas associated with the upper and lower auxiliary parabolic reflectors 10 and 11. Each primary antenna comprises two colinear dipoles 27 aligned with the focal line 13 of the reflector. The two dipoles of each primary antenna 40, 41 are connected by dipole lines 28 having equal lengths through a separate "branch" coaxial line 42 to an "auxiliary" line 43, the two branch lines 42 being of equal length. The auxiliary line 43 is connected to the principal line 33 and includes an adjustable phase shifter 44 and an adjustable attenuator 32.

In accordance with conventional practice, adjustable impedance transformers (not shown) are inserted at the line junctions and at the dipole junctions, for the purpose of matching impedances throughout the system. A conventional short-circuited quarter wave stub (not shown) is provided at the center of each dipole for rigidly connecting the inner coaxial line conductor to the outer coaxial line conductor through a high impedance. If desired, instead of employing the two special attenuators 32, the ratio of the amplitudes of the currents delivered to the main and auxiliary systems may be controlled by an impedance transformer at the junction of the principal line 33 with the main and auxiliary lines 31, 43. Also, if desired, after the adjustment of phase shifter 44 is determined an equivalent length of line may be substituted for the shifter.

The circuit operation, but not the directive operation, of the system is basically the same as that of the system described in the above-mentioned patent to C. A. Warren. Briefly considered, assuming device 34 is a radar transceiver, pulse energy is conveyed from device 34 through the attenuator 32 and over lines 33, 31, 30, 29 and 28 to the eight dipoles 27 of the main antenna system. The lobe switcher 39 functions to change the phase of one-half of the eight dipoles relative to the other half, the phases of the upper half, right half, lower half and right half being changed in succession. With the lobe switcher 39 disconnected the beam is aligned with the on-axis direction 8. With the lobe switcher operating, the beam is off-axis and dual plane lobe switching is obtained.

At the same time, pulses are conveyed through the attenuator 32 and phase shifter 44, and over lines 33, 43, 42 and 28 to the four dipoles 27 of the auxiliary antenna 9, the energies supplied to these dipoles being cophasal. As in the system of the Warren patent, the phase shifter 44 is adjusted so that the primary beams of the main and auxiliary antenna systems are cophasal. One or both of the attenuators 32 are adjusted, as explained hereinafter, so that the first minimum lobes of the resultant pattern are very small. As is now well-understood, the pulses emitted by the combined system are, after reflection at a target, returned to the antenna 1, 9 as echo pulses. The receiving circuit operation is the converse of the transmitting operation.

Considering in more detail the vertical or H-plane directive action of the main and auxiliary

primary antennas, the main primary antennas 25 and 26 constitute in this plane a linear array 45 comprising two vertically spaced antenna units of elements and having a vertical array axis aligned with the latus rectums 6; and the auxiliary primary antennas 40 and 41 constitute another linear array 46 comprising two vertically spaced elements and having an array axis aligned with the latus rectums 14. The broadside direction 8 is of course perpendicular to both of these vertical array axes and, with the lobe switcher 39 disabled, the angle between the direction of maximum action of each vertical array and the broadside direction 8 is zero, as already explained.

In the case of each of arrays 45, 46, the angle θ between the broadside direction 8 and any direction in the H-plane of null action, hereinafter termed a "null," is given by the equation

$$\theta = \sin^{-1} \frac{(2b-1)\lambda}{2L} \quad (1)$$

where L is the vertical spacing between the main or auxiliary primary antennas and b is any integer, the integers 1, 2, 3, 4, 5, etc. corresponding respectively to the first, second, third, fourth, fifth, etc. nulls.

For the auxiliary antenna 9, if

$$L = \frac{d}{3} \quad (2)$$

and

$$b = 1 \quad (3)$$

the angle, θ_{a1} , for the first nulls, is

$$\theta_{a1} = \sin^{-1} \frac{(2-1)3\lambda}{2d} = \sin^{-1} \frac{3\lambda}{2d} \quad (4)$$

For the main antenna 1, if

$$L = d \quad (5)$$

and

$$b = 2 \quad (6)$$

the angle, θ_{m2} , for the second nulls, is

$$\theta_{m2} = \sin^{-1} \frac{(4-1)\lambda}{2d} = \theta_{a1} \quad (7)$$

Similarly, for the spacings d and

$$\frac{d}{3}$$

we have for the second null, θ_{a2} , for the auxiliary system and the fifth null, θ_{m5} of the main system

$$\theta_{a2} = \sin^{-1} \frac{9\lambda}{2d} = \theta_{m5} \quad (8)$$

In accordance with the invention, the vertical spacing between the upper and lower auxiliary primary antennas 40, 41 is chosen equal to one-third of the vertical spacing between the upper and lower main primary antennas 25, 26. Hence, as is explained in detail below in connection with Figs. 4 and 5, with the lobe switcher 39 disabled, the first and second nulls of the H-plane pattern of the auxiliary system 9 are exactly aligned with the second and fifth nulls, respectively, of the main antenna system 1. With the lobe switcher 39 operating, the second main antenna null is switched from a point or angular direction close to and on one side of the fixed first auxiliary antenna null to a similar point on the other side of the last-mentioned null.

In one system actually constructed and tested at a wave-length, λ , equal to 27.8 centimeters, the dimensions M , N , m , n , d , $d/3$ and s were respectively 3.5λ , 7.35λ , 1.25λ , 2.5λ , 3.0λ , 1.0λ and 2.28λ , approximately. The horizontal spacing of the

main dipoles was about 0.75λ and the horizontal spacing of the suppressor dipoles was about 0.63λ .

Fig. 4 illustrates the H-plane directive patterns obtained for a system having the dimensions given above, the lobe switcher 39 being disabled and the beam being on-axis. In this figure, reference numerals 47, 48 and 49 denote the H-plane on-axis patterns, respectively, of the main antenna system 1, the auxiliary system 2 and the combined system 1, 2. The main pattern 47 includes a major lobe 50, the first nulls 51, the first minor lobes 52, the second nulls 53, the second minor lobes 54, the third nulls 55, and the third minor lobes 56. The auxiliary pattern 48 includes the maximum lobe 57, the first nulls 58 each aligned with a main null 53, and the minimum lobes 59. The resultant pattern 49 is equal to the algebraic sum of patterns 47 and 48, and includes the principal lobe 60, the sharp first nulls 61, the first subsidiary lobes 62, the flat second nulls 63 and the second subsidiary lobes 64.

The first minor lobes 52 are in phase with each other and opposite in phase to the major lobe 50 and, as stated previously, the maximum lobe 57 and the cophasal first minor lobes 52 are of opposite phase. The peak intensity of the maximum lobe is not adjusted, as in the system of the Warren patent, so as to have a slope intensity equal to the peak intensities of the first minor lobes. Instead, the maximum lobe intensity is adjusted to a relatively smaller value and such as to produce the first nulls 61 of the resultant pattern 49. By reason of the phase and amplitude adjustments, and especially by reason of the alignment of the second main nulls 53 with the first auxiliary nulls 58, the resulting first subsidiary lobes 62 are about 10 per cent of the peak value of the principal lobe 60, and are therefore substantially smaller than the first subsidiary lobes obtained in systems of the prior art. In addition, the higher order subsidiary lobes 64 are also less than 10 per cent of the principal lobe 60. Considered differently, the major lobe 50 and the first minor lobes 52 are merged by the maximum suppressor lobe 57. The second minor lobes 54 and the first minimum lobe 59 are antiphase so that the second minor lobes 54 are obliterated. Also, while the main antenna third minor lobe 56 is in phase with the auxiliary antenna first minimum lobe 59, the intensity of the main antenna third minor lobe is very small, whereby the resulting additive effect of these lobes is insignificant.

Referring to Fig. 5, reference numerals 65 and 66 designate the H-plane off-axis patterns, respectively, of the main system 1 and the combined system 1, 2 with the lobe switcher 39 operating so as to produce the dual plane lobe-switching operation. The main and auxiliary systems have the dimensions given above, and the fixed auxiliary pattern 47 is the same as in Fig. 4. As in Fig. 4, the major and maximum lobes are cophasal but, as explained in the Warren patent, whereas the phase of these lobes is zero for the on-axis condition, it is other than zero for the off-axis condition. The main pattern 65 is assumed to be switched or lobed up or down and includes a major lobe 67, the first nulls 68, the first minor lobes 69, the second nulls 70, and the second minor lobes 71. The resultant pattern 66 includes the principal lobe 72, the first nulls 73, the first subsidiary lobes 74, the second null 75, the third null 76, the dip 77 and the higher order subsidiary lobes 78. It will be observed from Figs. 4 and 5, that the first minor lobes become dis-

placed and modified in magnitude when the pattern is switched or lobed. The first minor lobes become smaller on the side toward which the major lobe is shifted and larger on the opposite side. As shown in Fig. 5, with the pattern switched, the first subsidiary lobes 74 and the higher order subsidiary lobes 78 are, as in the on-axis condition, only about ten per cent of the principal lobe 72.

The minor lobe reduction in the vertical plane is particularly advantageous in an anti-aircraft or searchlight control radar positioned close to the earth's surface and employed for detecting incoming enemy aircraft. Thus, assuming for the moment that the corresponding lower first minor lobes of the two H-plane patterns are large, and that the antenna axis is on target, that is, that the cross-over point of the two H-plane major lobes is aligned with the target, two equal intensity desired echo pulses are directly received on the two major lobes. At the same time, a pair of undesired echo pulses may be indirectly received, via the reflective earth's surface, on the two corresponding lower first minor lobes. Since the cross-over of these lobes may not be aligned with the direction of the wave reflected by the earth's surface, the undesired pulses may have unequal intensities. Also, since undesired and desired echo pulses combine to give the indication, an erroneous indication may be obtained. In short, with the antenna on target, if the minor lobes are large the two resulting echo pulses received may be unequal. By substantially reducing or eliminating the minor lobes, in accordance with the invention, false indications are avoided.

Thus far only the H-plane patterns have been discussed. The reduction of the minor lobes in the E or horizontal plane, while highly desirable, is not as important, because of the absence of the ground reflection effects, as the minor lobe reduction in the H-plane. In the E-plane, however, the suppressor antenna also functions to substantially reduce the minor lobes.

Although the invention has been explained in connection with a preferred embodiment, it is not to be limited to the embodiments described inasmuch as other apparatus may be utilized in successfully practicing the invention. Thus, the two main and the two suppressor reflectors may each be of a type other than cylindrical-parabolic as, for example, paraboloidal.

What is claimed is:

1. In combination, a first linear array comprising a pair of antenna elements spaced in a given plane a predetermined electrical distance, a second linear array comprising a pair of antenna elements spaced in a plane parallel to said plane a different electrical distance, said last-mentioned distance being a function, and equal to approximately one third, of the first-mentioned distance, a translation device, a pair of main lines connected to said device, a first pair of branch lines connecting said first-mentioned pair of elements to one of said main lines, a second pair of branch lines having equal lengths and connecting said second-mentioned pair of elements to the other main line, an adjustable phase shifter included in one of said main lines, and an adjustable attenuator included in one of said main lines.

2. In combination, a first directive antenna system comprising a first pair of cylindrical parabolic reflectors having a large double opening, a second directive antenna system comprising a second pair of cylindrical parabolic reflectors

having a small double opening, said reflectors facing in the same direction and having parallel focal lines, said large double opening containing said small double opening substantially, the spacing between the focal lines of the second pair of reflectors being one-third, and a function, of the spacing between the focal lines of the first pair of reflectors, a primary antenna aligned with the focal line of each reflector and comprising a plurality of dipoles, a translation device, all of said dipoles being simultaneously connected to said device.

3. In combination, a translation device, a main antenna system and an auxiliary suppressor antenna system each comprising a pair of cylindrical parabolic reflectors, said four reflectors facing the same direction and having horizontal axial planes, the ratio of the spacing between the horizontal axial planes of the two main reflectors to the spacing between the horizontal axial planes of the two auxiliary reflectors being equal to three, the opening of each reflector in the suppressor system being included in the opening of one of the reflectors in the main system, a separate primary antenna aligned with the focus of each reflector and comprising a plurality of dipoles, and separate lines connecting all of said primary antennas to the same translation device.

4. A combination in accordance with claim 3, the directive pattern of the main system in said given plane including two second nulls, a major lobe and two cophasal first minor lobes having a phase opposite to that of the major lobe, and the directive pattern of the suppressor system in said plane having a pair of first nulls and a maximum lobe included therebetween, said first nulls being aligned with said second nulls, substantially, and said major and maximum lobes being cophasal.

5. In a lobe switching system, a main antenna system and an auxiliary antenna system each comprising a pair of cylindrical parabolic reflectors, said four reflectors facing the same direction and having horizontal axial planes, the opening of each reflector in the auxiliary system being included in the opening of one of the reflectors in the main system, a plurality of dipoles aligned with the focus of each reflector, a first pair of lines connected to the dipoles of the main antenna, a second pair of lines connected to the dipoles of the auxiliary antenna, a translation device, a main coaxial line connecting the first pair of lines to said device, an auxiliary co-

axial line connecting the second pair of lines to said device, an adjustable phase control means included in one of said coaxial lines, and amplitude control means included in one of said coaxial lines.

6. In a dual plane lobe switching or conical scanning antenna system, a main directive antenna system comprising a large upper cylindrical parabolic reflector and a large lower parabolic reflector, a pair of linear subarrays aligned with the focal line of each main reflector and each comprising a plurality of horizontal dipoles, a transceiver, a main coaxial line and an auxiliary coaxial line connected thereto, separate lines connecting the four subarrays to said main coaxial line, means connected to said separate lines for shifting the phase of the currents in two of said separate lines simultaneously and in all of said separate lines successively, an auxiliary directive antenna system positioned adjacent said main system and comprising a small upper cylindrical parabolic reflector and a small lower parabolic reflector, a linear array aligned with the focal line of each auxiliary reflector and comprising a plurality of horizontal dipoles, said linear array being connected to said auxiliary coaxial line, the vertical spacing between the focal lines of the two small reflectors being equal to one-third the vertical spacing between the focal lines of the two large reflectors, means in one of said coaxial lines for controlling the relative amplitudes of the currents in said coaxial lines, and means in one of said coaxial lines for rendering the currents in the dipoles of the linear array in phase at any instant with the currents in the dipoles of two subarrays.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,808,867	Stone	June 9, 1931
1,908,595	Franklin et al.	May 9, 1933
2,033,390	Moser	Mar. 10, 1936
2,095,083	Renatus	Oct. 5, 1937
2,342,721	Boerner	Feb. 29, 1944
2,354,254	Gerhard	July 25, 1944
2,411,034	Gluyas et al.	Nov. 12, 1946
2,416,155	Chubb	Feb. 14, 1947
2,424,982	Higgins et al.	Aug. 5, 1947