

[54] RECEIVING ANTENNA SYSTEM

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[22] Filed: Feb. 13, 1962

[21] Appl. No.: 173,612

[52] U.S. Cl. 343/100 R, 343/100 SA, 343/854,
343/911 L

[51] Int. Cl. G01s 3/74, H01q 3/26, H01q 15/08

[58] Field of Search 343/100, 100.6, 854,
343/911, 911 L

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EXEMPLARY CLAIM

9. A receiving antenna system comprising a plurality of individual receiving elements distributed in a spherical array,

a like plurality of heterodyne mixers,

a plurality of parametric amplifiers, each of said parametric amplifiers coupling one of said individual receiving elements to a first input of a corresponding one of said heterodyne mixers, each of said parametric amplifiers being adapted to operate in the lower-sideband, up-conversion mode,

a pump signal generator, means coupling said pump signal generator to each of said parametric amplifiers, said last-mentioned coupling means providing the same relative phase shift between said pump signal generator and each of said parametric amplifiers,

a spherical Luneberg lens, a plurality of energy pick-up means distributed over the surface of said lens, the distribution of said pick-up means on said lens corresponding to the distribution of said individual receiving elements on said array,

means connecting each of said energy pick-up means to a second input of the heterodyne mixer associated with the corresponding one of said individual receiving elements,

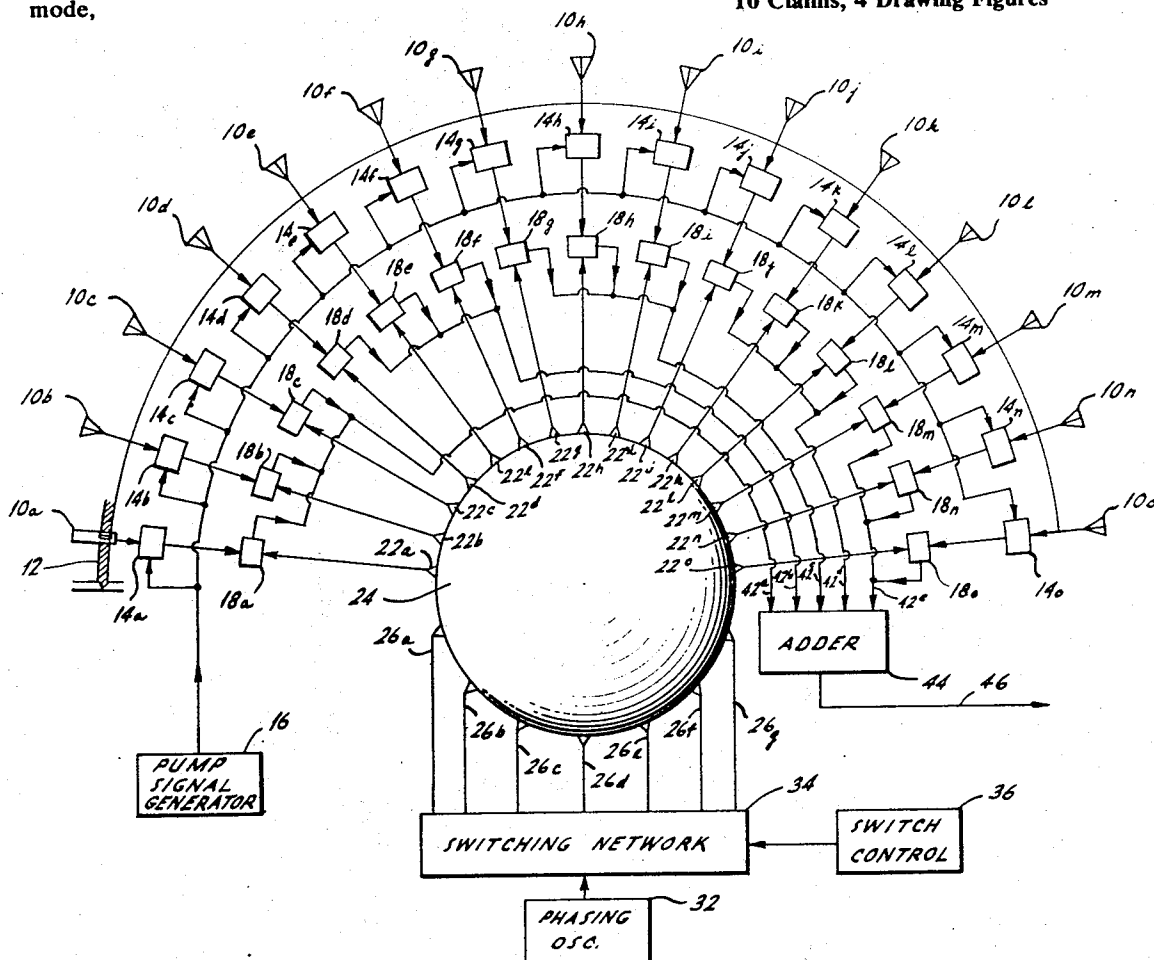
a plurality of feed horns distributed over a hemispherical area of said lens,

a phasing oscillator,

switching means controllable to connect said phasing oscillator to said energy feed horns one at a time in a selected sequence,

the ratio of the diameter of said Luneberg lens to the diameter of said spherical array being equal to the ratio of the frequency of the signal supplied by said individual receiving element to the frequency of the signal supplied by said phasing oscillator, and means for combining the output signals of said heterodyne mixers.

10 Claims, 4 Drawing Figures



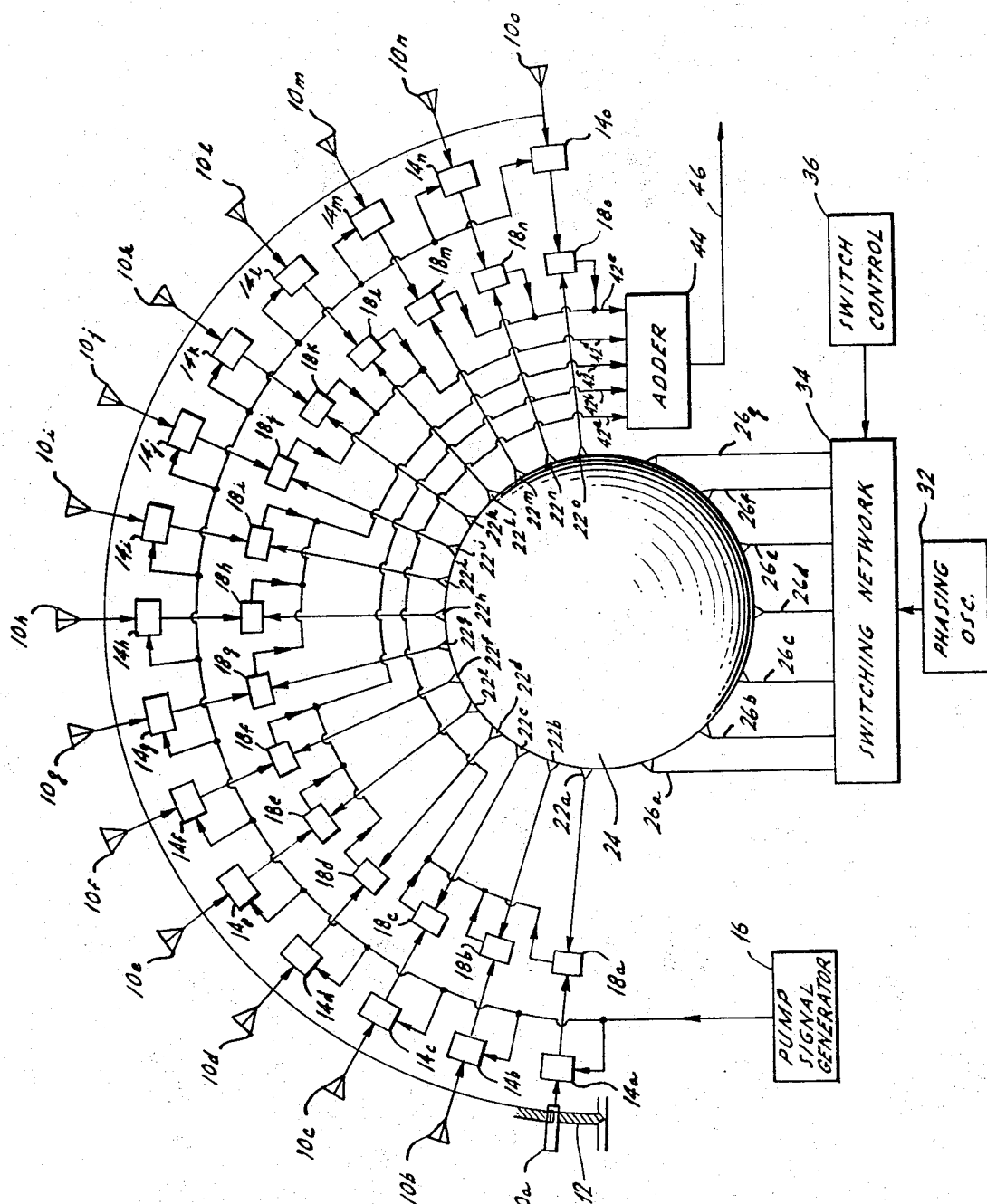


FIG. 1.

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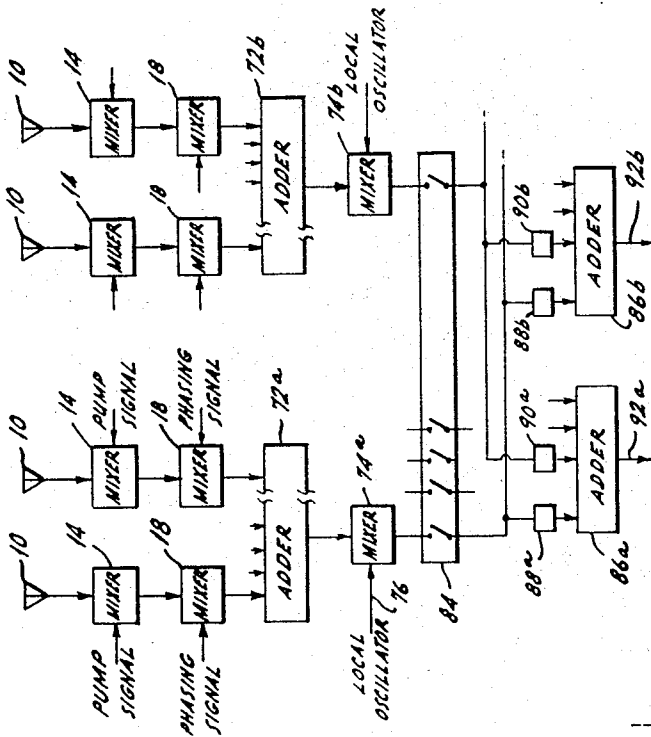


FIG. 4.

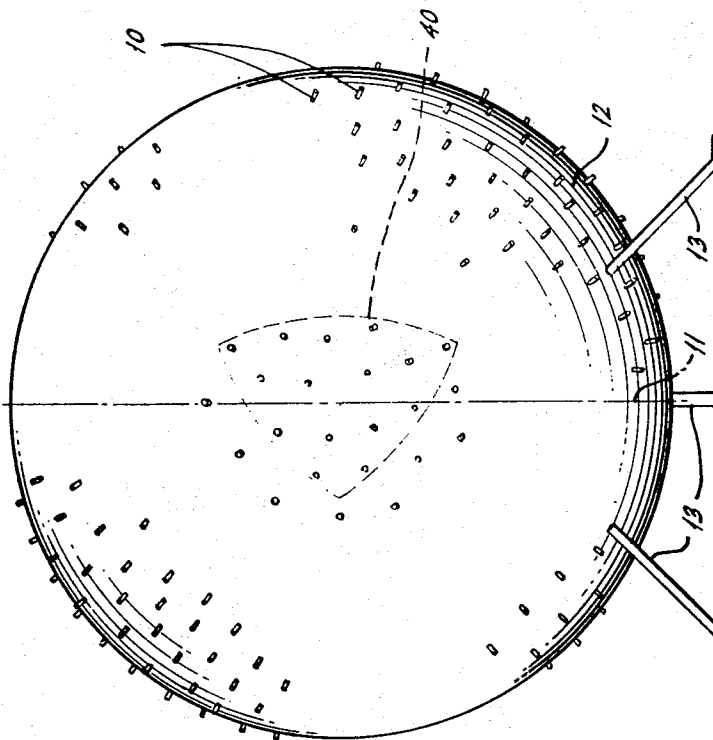


FIG. 2.

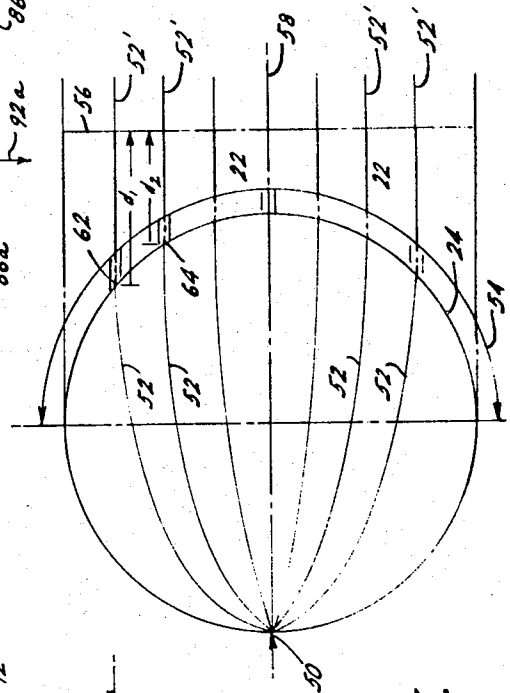


FIG. 3.

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RECEIVING ANTENNA SYSTEM

The present invention relates to directional signal receiving systems and more particularly to electronically scannable directional signal receiving systems.

Long range surveillance systems require antenna systems which can segregate energy received from a narrow solid angle in space from energy illuminating the antenna from other locations in space. That is, the antenna must have a narrow receiving beam pattern. The energy received by the antenna system may be the energy radiated by a nearby transmitter which is reflected by objects in space. In many instances it is necessary for each surveillance system to provide complete surveillance in all directions from the system. Thus it is necessary that the receiving beam pattern be scannable through a large solid angle. For various reasons well known in the radar art it is necessary that the beam or beams formed by the antenna system scan rapidly through the selected solid angle of desired coverage. Large arrays of individual antenna elements or large reflectors are required to obtain narrow reception angles. Mechanical scanning of these large arrays is not practical. It is difficult to obtain the desired hemispherical scan with large mechanically scanned arrays and it is impossible to obtain the required scanning speed with massive mechanically scanned arrays.

For these and other reasons the preferred form of narrow beam, wide coverage, rapid scan arrays comprises a large number of individual antenna elements arranged on a spherical supporting surface with means for electronically phasing the energy supplied to or received from the individual elements. Practical long-range, narrow-beam surveillance antenna will require several thousand individual elements arranged in a spherical array and systems have been proposed which employ several hundred thousand individual elements. To obtain the necessary narrow beam width in a receiving antenna comprising elements arranged in a spherical array it is necessary that the phase of the signal provided by each element be altered by an amount determined by the position of that element in the array and the desired angle of the beam. The phase corrected signals are then added together to form an output signal which is representative of energy received from the selected narrow solid angle of space. Since the desired beam angle is constantly changing as the beam is scanned through the selected angle of coverage of the system, it is necessary that the phase correction applied to the signal provided by each element be varied accordingly.

The difficulties involved in electronically varying the phase of several thousand or several hundred thousand received signals will be readily apparent to those skilled in the art. It has been suggested that the proper phasing of the received signals could be obtained by feeding the signals from the plurality of elements to appropriate points on the surface of a spherical Luneberg lens and extracting an output signal from a point on the opposite hemisphere of the lens. This proposal has the disadvantage that the received signals, which are usually at a very low energy level, would be further attenuated by their passage through the Luneberg lens. It is usually impossible to compensate for the attenuation of the received signal by increasing the already extremely high output power levels of the long range transmitters. Furthermore a Luneberg lens equal in diameter to the diameter of the array would be required.

Therefore it is an object of the present invention to provide an electronically scannable, highly directive antenna system which minimizes the attenuation of received signal energy.

It is a further object of the invention to provide novel means for phasing the signals received from a plurality of spherically arranged elements which does not attenuate the received signal.

A further object of the present invention is to provide an electronically variable phasing system for a plurality of received signals.

An additional object is to provide a directional signal receiving system which minimizes the size of the phase shifting elements of the system.

In general these and other objects thereof are achieved by providing means for increasing the frequency of the signals received by the individual elements without altering the relative phases of these signals. A locally generated phasing signal is passed through a Luneberg lens or equivalent phase shifting means to provide a plurality of differently phased output phasing signals. The respective output phasing signals are then heterodyned with the frequency shifted signals derived from corresponding individual elements of a spherical array. The rephased received signals produced by the heterodyning are then additively combined to provide a signal which represents the energy returned from a preselected narrow solid angle of space. Means are also provided for varying the point of application of the locally generated phasing signals to the Luneberg lens, thereby to vary the phase of each of said plurality of output phasing signals. This varies the orientation of the beam in space.

For a better understanding of the present invention together with other and further objects thereof, reference should now be made to the following detailed description wherein

FIG. 1 is a diagrammatic representation of a selected portion of one preferred embodiment of the invention; FIG. 2 is a side view of an antenna system in accordance with the present invention;

FIG. 3 is a diagram which explains in part the operation of the system of FIGS. 1 and 2; and

FIG. 4 is a block diagram showing one preferred form of beam forming system which may be employed with the antenna system of FIG. 1.

In FIGS. 1 and 2 a plurality of elements 10 are randomly distributed over a spherical conductive support structure 12. The average spacing between elements 10 is slightly over one-half wavelength. While a regular spacing of elements 10 may be employed, it can be shown that narrower bandwidths can be obtained for a given number of elements if they are randomly arranged with a spacing which is, on the average, greater than a half wavelength. The few hundred elements 10 shown in FIG. 2 will provide a relatively low resolution beam. In very high resolution systems, several thousand or several hundred thousand elements may be employed. The antenna elements 10 may have any desired configuration, for example they may be simple open-ended circular waveguides extending through the spherical outer surface of supporting structure 12. Structure 12 may be supported in a slightly elevated position by a plurality of legs 13.

The 15 elements 10^a-10^o shown in FIG. 1 may be taken as representative of the elements lying on or near the broken line 11 on the spherical surface 12 of FIG.

2. Each of the elements 10^a-10^o feeds directly into a corresponding one of 15 parametric amplifiers 14^a-14^o. The parametric amplifiers 14^a-14^o are supplied with a high frequency pump signal from pump signal generator 16. The parametric amplifiers 14^a-14^o preferably operate in the lower sideband up-conversion mode so that the frequency of the output signal is higher than that of the input signal.

For reasons which will become clearer as the description of the invention proceeds, it is necessary to maintain a known phase relationship between the signals derived from each of the elements 10 of FIG. 2. For this reason the connection between pump signal generator 16 and the parametric amplifiers 14 should be such that the pump signal is supplied in like phase to all of the parametric amplifiers. This can be accomplished by employing equal lengths of transmission lines between generator 16 and each of the amplifiers 14. If supporting surface 12 is large and only a relatively few elements 10 are employed, conventional coaxial lines may be employed for the various signal paths. However if several thousand radiators are employed it is usually preferable to employ printed circuit techniques for the signal processing circuits and transmission lines.

The output of each of the parametric amplifiers 14^a-14^o feeds to a corresponding one of heterodyne mixers 18^a-18^o. Again it should be remembered that there will be one heterodyne mixer 18 for each of the antenna elements 10 on the spherical surface 12. Each mixer 18 will receive an input signal from a corresponding one of the amplifiers 14. A second input to each of the heterodyne mixers 18 is connected to a corresponding one of the pick-up horns 22 which are mounted on the surface of a Luneberg lens 24. As is well known, a Luneberg lens is a sphere of dielectric material in which the relationship between relative dielectric constant and fractional radius is

$$k = 2 - r^2$$

in the range $0 \leq r \leq 1$; where k is the dielectric constant at any point in the spherical volume and r is the distance from the center of the sphere to that point. Thus it will be seen that the relative dielectric constant varies between 1 at the surface of the lens and 2 at the center of the lens. Pick-up horns 22 may be simple, open ended circular waveguide sections. Again the specific showing in FIG. 1 of mixers 18^a-18^o connected to horns 22^a-22^o is representative of the similar connections made for the mixer-horn pairs associated with each of the elements 10 of FIG. 2. The transmission lines from parametric amplifiers 14 to mixers 18 should be of equal length and the transmission lines from pick-up horns 22 to mixers 18 should be of equal length (or differ by an integral number of wavelengths at the frequency of the signals carried by these transmission lines) in order to preserve the proper phasing of the signals at the output of mixer 18.

Energy is supplied to the Luneberg lens 24 by way of a plurality of feed horns 26^a-26^o. While only seven feed horns 26^a-26^o are shown in FIG. 1, it is to be understood that a relatively large number of feed horns 26 will be required, although in general there will be fewer feed horns 26 than there are pick-up horns 22. In the simplest embodiments of the invention one feed horn will be required for each direction in which the beam from the entire system is to point. For reasons which will be given in detail presently it is necessary that the

pick-up horns 22 be distributed over the hemisphere of the Luneberg lens 24 which is remote from the presently active feed horn 26. Thus it will be seen that if the feed horns 26 are arranged on lens 24 so as to provide hemispherical coverage of the scanning beam it will be necessary to intermix feed horns 26 and pick-up horns 22 on the hemispherical surface of the lens 24 occupied by the feed horns 26. Since the pick-up horns 22 preferably have a random distribution corresponding to the random distribution of radiating elements 10, this intermixing of feed horns 26 with pick-up horns 22 can usually be accomplished without difficulty.

Energy is supplied to feed horns 26 from a phasing oscillator 32 by way of switching network 34. Switching network 34 is preferably an electronic switch means, such as a plurality of ferrite or crystal diode gate means, which connects a selected one of the feed horns 26 to phasing oscillator 32. Block 36 diagrammatically represents means for controlling the switching action of network 34. Switch control 36 may be a digital computer network which can be set to connect each one of the feed horns in turn to phasing oscillator 32, thereby to provide a programmed scan of the entire coverage area. Alternatively, switch control 36 may respond to information received by the antenna system to track a selected target in space with the beam from the antenna system. Switch control 36 may alternate between these two functions as the requirements of the situation demand.

The mixers 18 associated with each of the elements 10 are connected together in groups, each group having a common output. The mixers 18 in a group are preferably those mixers associated with the elements 10 lying within a preselected sector of the surface 12, for example the sector enclosed by the broken line 40 in FIG. 2. In FIG. 1 this is represented by the common connection 42^a to the outputs of mixers 18^a, 18^b and 18^c, the connections 42^b to the outputs of mixers 18^d-18^f, the connection 42^c to the outputs of mixers 18^g-18ⁱ, the output connection 42^d to the outputs of mixers 18^j-18^l and the output connection 42^e to the output of mixers 18^m-18^o. In one embodiment of the invention all of the outputs from all groups may be connected to a single adder circuit 44. In such an embodiment it is again important that the several output connections 42 provide equal phase shifts to the signals passing therethrough. This is most easily accomplished by making the connections 42 of equal length.

Adder 44 is provided with a single output connector 46. As will be shown in more detail presently the signal on output connection 46 represents the energy received from a narrow solid angle in space, the position of the solid angle being determined by the position of the feed horn 26 which is then energized.

The various elements of the combination shown in FIG. 1, such as amplifiers 14, mixers 18, lens 24 and the circuits associated therewith, pump signal generator 16 and adder 44, may be located in any convenient place either within or outside the spherical support 12 provided the above-mentioned limitations on electrical lengths of transmission lines are observed. However considerable saving of space and complexity can be achieved by supporting lens 24 at the center of spherical support 12. The mechanical support may take the form of mechanical struts (not shown) extending from the support 12 to suitable positions on lens 24. The ratio of the diameter of spherical support 12 to the di-

ameter of lens 24 should be equal to the ratio of the frequency of the signal supplied by phasing oscillator 32 to the frequency of the signal received by elements 10. Therefore if oscillator 32 supplies a signal which has a frequency which is several times the frequency of the received signal, there will be ample room between lens 24 and support 12 for the remainder of the circuit elements. Amplifier 14, mixer 18 and the transmission lines associated therewith may take the form of multi-layer strip line circuits conforming to the inner surface of support 12.

The system of FIG. 1 operates in the following manner. Parametric amplifiers 14 amplify and change the frequency of the signals supplied thereto by the individual antenna elements 10. However the output signals supplied by amplifiers 14 have the same relative phases as the signals provided by elements 10. As stated above, the parametric amplifiers operate in the lower sideband, up conversion mode. In a typical embodiment the input signal from element 10 may have a frequency of the order of 3 kilomegacycles, while the pump signal from generator 16 may have a frequency of the order of 11 kilomegacycles. This will produce an output or idler frequency signal having a frequency of the order of 8 kilomegacycles. These frequencies are given only by way of example and the operation of the signal receiving system of FIGS. 1 and 2 is not limited to these frequencies or these frequency ranges.

If the signal receiving system shown in FIG. 1 is to be employed with a transmitter which provides an output signal which changes in frequency from time to time, it may be desirable to cause the frequency of the pump signal generator 16 to change in frequency by a corresponding amount, thereby to cause the frequency of the signal supplied by mixer 18 to be substantially constant.

Each of the elements 10 will receive energy from a comparatively wide angle in space. A highly directive pattern for the system is achieved by combining the signals from the individual radiators 10 so that the signals from the desired direction of reception are combined in like phase, thereby to provide mutual reinforcement while signals from all other directions are combined so as to produce mutual cancellation.

The elements 10 are not all at the same distance from any source in space. Therefore, to cause the receiving system of FIGS. 1 and 2 to have a highly directive pattern oriented in a particular direction, it is necessary to shift the phases of the signals derived from the individual elements 10 by an amount which is dependent on the desired direction of reception and the position of the individual elements 10.

In the present invention, the desired phase relationship of the signals from all of the elements 10 is established for a given direction of reception by heterodyning each of the multi-phase signals supplied by the individual amplifiers 14 with a corresponding phase correction signals supplied by Luneberg lens 24. The plurality of phase correcting signals are generated in the following manner. A constant frequency signal of any arbitrary phase is supplied by oscillator 32 to one of the feed horns 26 of Luneberg lens 24. In the example chosen above this signal may have a frequency of the order of 12 kilomegacycles. The particular horn 26 selected by switching network 34 is determined by the selected direction of reception of the receiving system of FIGS. 1 and 2. It will be helpful to consider Lune-

berg lens 24 as a miniature of support 12 with pickup horns 22 replacing elements 10. It will also be helpful to assume that this miniature of support 12 has the same orientation in space or support 12 although in practice it may have any desired orientation. If this assumption is made the horn 26 that is selected is the one diametrically opposite the selected direction of reception.

As shown in FIG. 3, energy supplied at any point 50 on a spherical Luneberg lens will be focused into parallel rays 52' emerging from the other side of the sphere. Within the lens 24 the energy follows the elliptical paths 52. It will be understood that there are an infinite number of such paths 52 so that the entire hemispherical surface 54 opposite the point 50 is illuminated. The relative effective path lengths within the lens 24 are such that the energy in all of the paths 52', which are extensions of the paths 52 within the lens 24, will be in like phase at any plane 56 which is perpendicular to a line 58 drawn through point 50 and the center of lens 24. Thus the phase of the energy at any point 62 on the surface 54 of the lens 24 will differ from the phase of the energy at any other point 64 by an amount which is proportional to the difference in the distance d_1 and d_2 from points 62 and 64 respectively to plane 56.

I have discovered that if the ratio of the diameter of lens 24 to the diameter of support 12 is equal to the ratio of the frequency of the energy returned to antenna elements 10 to the frequency of the signal supplied to feed horn 26, and if the position of the pickup horns 22 on lens 24 correspond to the position of elements 10 on surface 12, then the phase difference between the signals received by any pair of pickup horns 22 will be equal in magnitude but opposite in sign to the phase difference between the signals received by the corresponding pair of antenna elements 10 from points in space which correspond to points along the line 58 of FIG. 4. The heterodyning of the signals from horn 22 with the signal supplied to mixer 18 from the corresponding element 10 and amplifier 14 will result in signals which are in phase for points in space which correspond to points along the line 58 of FIG. 4. Thus the antenna system of FIG. 1 will be highly directive with the position of the axis of directivity determined by the position of the energized feed horn 26 on lens 24. The mixers 18 also perform the second function of reducing the 8 kilomegacycle signals supplied by amplifiers 14 to a first I.F. frequency of the order of 4 kilomegacycles.

The beam pattern may be caused to scan any predetermined angle in space by varying the point at which energy is supplied to lens 24. That is, for each horn 26 on lens 24 there is a corresponding direction of maximum response of the antenna system. While in some instances it may be possible to provide means for mechanically scanning a single feed horn 26 over the surface of lens 24, in most applications of the signal receiving system it will be preferable to provide a plurality of feed horns 26 which are energized one at a time by switching network 34.

It will be seen that approximately half of the receiving elements 10 are shadowed by support 12 from any given direction in space. These shadowed elements 10 provide no useful signal from the desired direction in space and may pick up stray energy at the selected frequency reception due to reflection of such energy from nearby objects. This would tend to produce the effect of sidelobes or backlobes in the overall pattern of the

antenna system. Therefore it may be desirable to replace the direct connections from amplifiers 14 to mixers 18 with a switchable connection controlled by switching network 34 or switch control 36. This can be accomplished without difficulty since there is a direct relationship between the feed horn 26 which is energized and the radiators 10 which are receiving useful signals from the selected beam direction. If such a switching arrangement is employed it will be preferable in most instances to include only those radiators which are within a solid angle of approximately 120° centered on the selected beam direction. The radiators on the periphery of the then active hemisphere of the array will have very low response in a selected direction of reception. Even without the switchable connection between the amplifiers 14 and mixers 18, the side lobes of the pattern of the system of FIG. 1 will be small compared to the main lobe for the reason that the mixers 18 associated with the shadowed elements 10 receive no local oscillator signal from lens 24. As a result the output signals from the heterodyne mixers 18 associated with the shadowed elements 10 will be at a very low level compared to signals provided by the mixers associated with the elements 10 on the illuminated side of the array shown in FIGS. 1 and 2.

FIG. 4 shows an alternative means for combining the signals from individual elements 10 to provide a cluster of highly directive beams which may be scanned at a rapid rate through a wide angle. Circuit components in FIG. 4 corresponding to like components in FIG. 1 have been identified by the same reference numerals. Adder 72a receives signals from a group of elements 10 within a selected sector of surface 12. For example, adder 72a may receive signals from sector 40 of FIG. 2. Similarly adders 72b receive signals from elements 10 within a different sector. Only two adders 72 are shown in FIG. 4 but in practice several hundred or several thousand such adders may be employed. For example, in an antenna system having thirty thousand elements 10, 200 adders 72 may be employed, each adder 72 receiving signals from one hundred fifty elements 10. It will be seen that adders 72 of FIG. 4 correspond to the common connections 42 of FIG. 1. The combined sector signal provided by each adder 72 is supplied to one input of a corresponding mixer 74. A local oscillator signal is supplied in like phase or in predetermined different phase to a second input 76 of each of the mixers 74. The local oscillator signal may have a frequency of the order of 3.97 kilomegacycles. Thus in the illustrative example given above the output signals of 74 would have a frequency of approximately 30 megacycles. Mixers 74 represents means for reducing the signal provided by each of the adders 72 to video frequency or a lower *i-f* frequency. These mixers 74 may be omitted or placed in a different point in the circuit if desired.

The outputs of mixers 74 are connected to a switching network 84 which is coordinated with switching network 34 of FIG. 1 so that only elements 10 lying in a solid angle of approximately 120° centered about the selected average direction of the beams are connected to circuits which follow switching network 84. In the illustrative example given above, switching network 84 may connect sixty of the mixers 74 to circuits which follow network 84. The sixty mixers 74 which are so connected will depend on which horn 26 is energized

and will change as different horns 26 are energized by switching network 34 of FIG. 1.

The output connection of switching network 84 which corresponds to mixer 74a is connected to each one of a plurality of adder circuits 86, represented in FIG. 4 by adder circuits 86a and 86b, by way of phase shifting networks 88a, 88b etc. In a similar manner the output of switching network 84 which corresponds to the output of mixer 74b is connected to each of the adders 86 by way of phase shifters 90a, 90b, etc. In general there will be one adder 86 for each beam in the cluster. In the example chosen above, ten adders 86 may be provided to produce a cluster of ten highly directive beams, oriented in the same general direction but each slightly displaced from the others. Thus the signal appearing at the single output 92a of adder 86a will represent the target echo signals received by one beam of the cluster and the signal at output 92b of the adder 86b will represent target echo signals received by a second beam of the cluster.

The system of FIG. 4 operates in the following manner. Mixers 14 and 18 operate in exactly the same manner as the corresponding mixers of FIG. 1 to bring the output signals from mixers 18, and hence adders 72, into like phase for a given direction in space. As in the system of FIG. 1, this direction is selected by selecting the horn 26 which is energized. This, in turn, determines the relative phases of the phasing signals supplied to mixers 18.

Switching network 84 selects only the active or unshadowed elements 10 on the surface 12. Phase shifters 88, 90 and the shifters associated with the other active mixers 74 alter the phases of the signal supplied by mixers 74 so that signals from a direction in space slightly different from the selected direction are in phase at the output of each of the adders 86. The phase shifts which must be provided by phase shifters 88, 90 etc. are equal to those required to steer or deflect the beam of a planar array of elements by the same angle from the normal to the array. This difference in direction may be of the order of 1° or less. As a result, the signal at output 92 of each of the adders 86 represents signals received from a slightly different direction in space. A cluster of beams of this type is useful in locating, tracking and determining the characteristics of unknown targets in space.

While the invention has been described with reference to what are at present considered the preferred embodiments thereof, I desire the scope of the invention to be limited only by the appended claims.

I claim:

1. A receiving antenna system comprising
 - a plurality of individual receiving elements distributed in a spherical array,
 - a like plurality of heterodyne mixers, each individual element being coupled to one input of a corresponding one of said heterodyne mixers,
 - a spherical Luneberg lens,
 - means for supplying oscillatory energy to selected points on said lens,
 - a plurality of energy pick-up means distributed over the surface of said lens,
 - means connecting each of said energy pick-up means to a second input of a corresponding one of said heterodyne mixers,
 - and means for combining the output signals of said plurality of heterodyne mixers.

2. A receiving antenna system comprising
 - a plurality of individual receiving elements distributed in a spherical array,
 - a like plurality of heterodyne mixers, each individual element being coupled to one input of a corresponding one of said heterodyne mixers,
 - a spherical Luneberg lens,
 - a plurality of energy pick-up means distributed over the surface of said lens, the distribution of said pick-up means on said lens corresponding to the distribution of said individual receiving elements on said array,
 - means connecting each of said energy pick-up means to a second input of the heterodyne mixer associated with the corresponding one of said individual receiving elements,
 - means for supplying oscillatory energy to selected points on the surface of said Luneberg lens, and
 - means for combining the output signals of said plurality of heterodyne mixers.
3. A receiving antenna system comprising
 - a plurality of individual receiving elements distributed in a spherical array,
 - individual frequency changing means associated with each of said individual receiving elements, said individual frequency changing means being adapted to increase the frequency of the signal supplied by said individual receiving elements without altering the relative phases of the signals supplied by said individual receiving elements,
 - a like plurality of heterodyne mixers, each individual frequency changing means being coupled to one input of a corresponding one of said heterodyne mixers,
 - a spherical Luneberg lens,
 - means for supplying oscillatory energy to selected points on the surface of said Luneberg lens,
 - the ratio of the diameter of said Luneberg lens to the diameter of said spherical array of individual elements being equal to the ratio of the frequency of the signal supplied by said individual elements to the frequency of the signal supplied to said lens,
 - a plurality of energy pick-up means distributed over the surface of said lens, the distribution of said pick-up means on said lens corresponding to the distribution of said individual receiving elements on said array,
 - means connecting each of said energy pick-up means to a second input of the heterodyne mixer associated with the corresponding one of said individual receiving elements, and
 - means for combining the output signals of said plurality of heterodyne mixers.
4. A receiving antenna system according to claim 3 wherein said means for supplying oscillatory energy to said Luneberg lens comprises:
 - a plurality of energy feed horns distributed over the surface of said lens,
 - a phasing signal generator, and
 - switching means controllable to connect said phasing signal generator to said energy feed horns one at a time in a selected sequence.
5. A receiving antenna system in accordance with claim 4 wherein said energy feed horns are distributed over substantially an entire hemisphere of said Luneberg lens.

6. A receiving antenna system in accordance with claim 3 wherein said means for combining the output signals of said plurality of heterodyne mixers comprises means for additively combining the output signals of all of said mixers without relative change of phase.
7. A receiving antenna system in accordance with claim 3 wherein said means for combining the output signals of said plurality of said heterodyne mixers comprises:
 - a plurality of adder means,
 - phase shifting means connecting a selected set of said heterodyne mixer means to each of said adder means, the signals from said heterodyne mixer means being supplied to said different adder means in different phases thereby to provide a plurality of output signals each representative of energy received from a different direction.
8. A receiving antenna system in accordance with claim 3 wherein said means for combining the output signals of said plurality of heterodyne mixers comprises:
 - a plurality of adder means, each adder means being coupled to the outputs of a plurality of those said heterodyne mixers associated with individual receiving elements located in the same limited sector of said spherical array,
 - a second plurality of adder means,
 - and means including switching means and phase shifting means for coupling, selectively, the outputs of selected ones of said first plurality of adder means to inputs of each of said second plurality of adder means, the signal from individual adder means of said first plurality being supplied in different phases to different individual adder means of said second plurality.
9. A receiving antenna system comprising a plurality of individual receiving elements distributed in a spherical array,
 - a like plurality of heterodyne mixers,
 - a plurality of parametric amplifiers, each of said parametric amplifiers coupling one of said individual receiving elements to a first input of a corresponding one of said heterodyne mixers, each of said parametric amplifiers being adapted to operate in the lower-sideband, up-conversion mode,
 - a pump signal generator,
 - means coupling said pump signal generator to each of said parametric amplifiers, said last-mentioned coupling means providing the same relative phase shift between said pump signal generator and each said parametric amplifiers,
 - a spherical Luneberg lens,
 - a plurality of energy pick-up means distributed over the surface of said lens, the distribution of said pick-up means on said lens corresponding to the distribution of said individual receiving elements on said array,
 - means connecting each of said energy pick-up means to a second input of the heterodyne mixer associated with the corresponding one of said individual receiving elements,
 - a plurality of feed horns distributed over a hemispherical area of said lens,
 - a phasing oscillator,
 - switching means controllable to connect said phasing oscillator to said energy feed horns one at a time in a selected sequence,

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the ratio of the diameter of said Luneberg lens to the diameter of said spherical array being equal to the ratio of the frequency of the signal supplied by said individual receiving element to the frequency of the signal supplied by said phasing oscillator, and means for combining the output signals of said heterodyne mixers.

10. A receiving antenna system comprising:
a plurality of individual receiving elements distributed in a spherical array,
a like plurality of heterodyne mixers, each individual receiving element being coupled to one input of a

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corresponding one of said heterodyne mixers, a spherical Luneberg lens,
means for supplying oscillatory energy to selected points on said lens,
a plurality of energy pickup means distributed over the surface of said lens; means connecting a second input of each of said heterodyne mixers to a corresponding one of said energy pickup means, and means for combining the output signals of said plurality of heterodyne mixers.

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