

Sept. 20, 1966

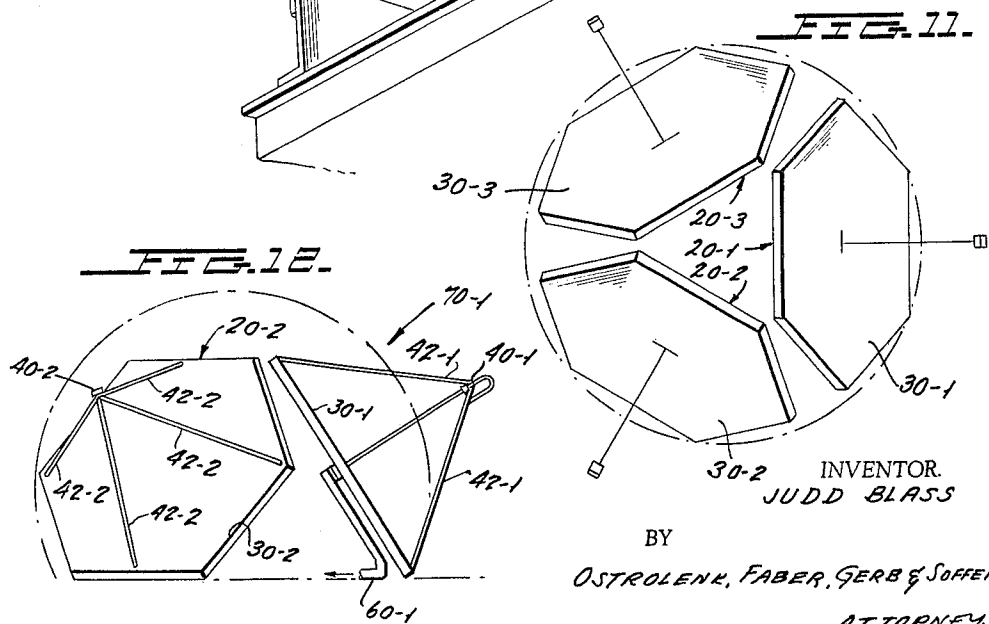
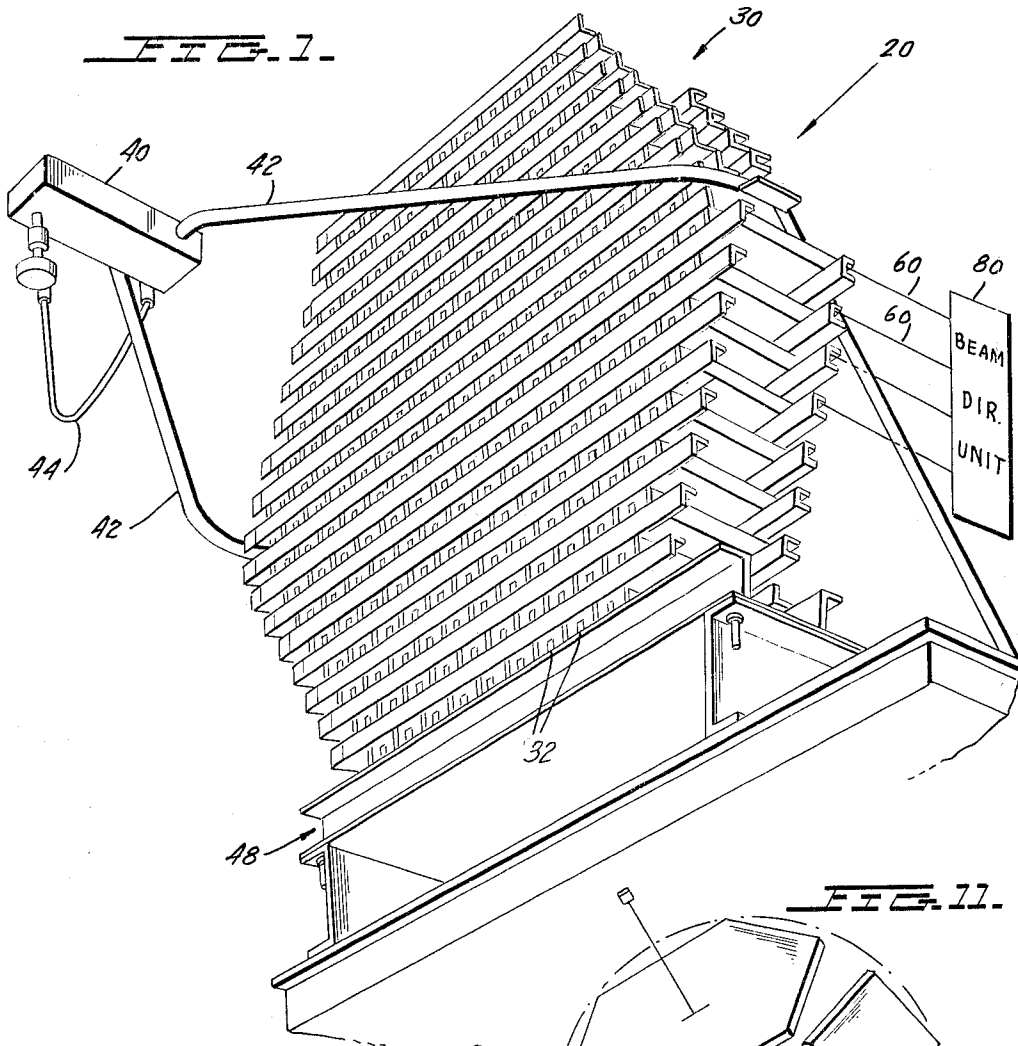
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3,274,601

ANTENNA SYSTEM WITH ELECTRONIC SCANNING MEANS

Filed Dec. 12, 1962

5 Sheets-Sheet 1



Sept. 20, 1966

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3,274,601

ANTENNA SYSTEM WITH ELECTRONIC SCANNING MEANS

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5 Sheets-Sheet 2

FIG. 2.

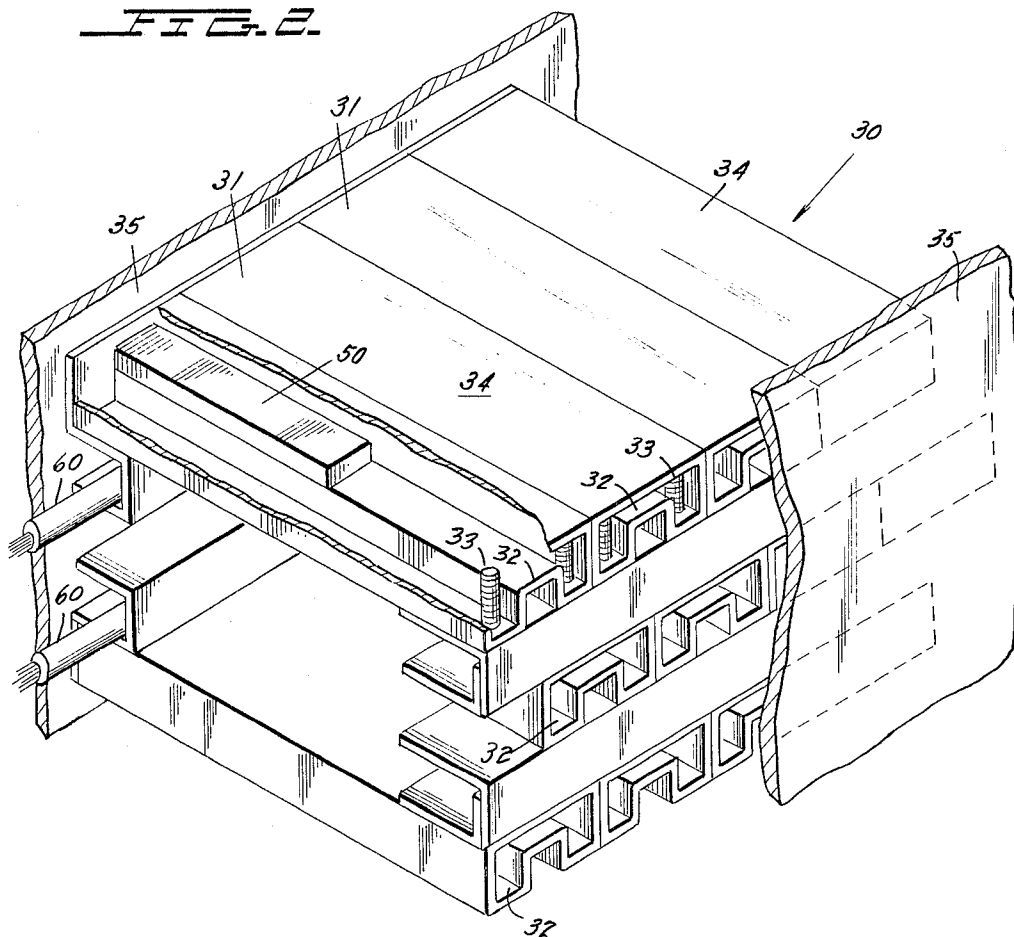
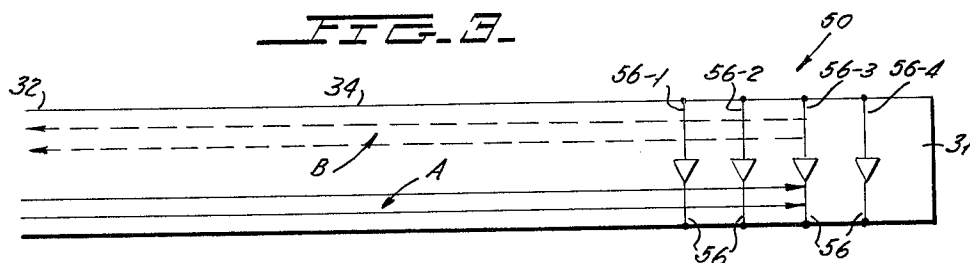


FIG. 3.



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Filed Dec. 12, 1962

5 Sheets-Sheet 3

FIG. 4

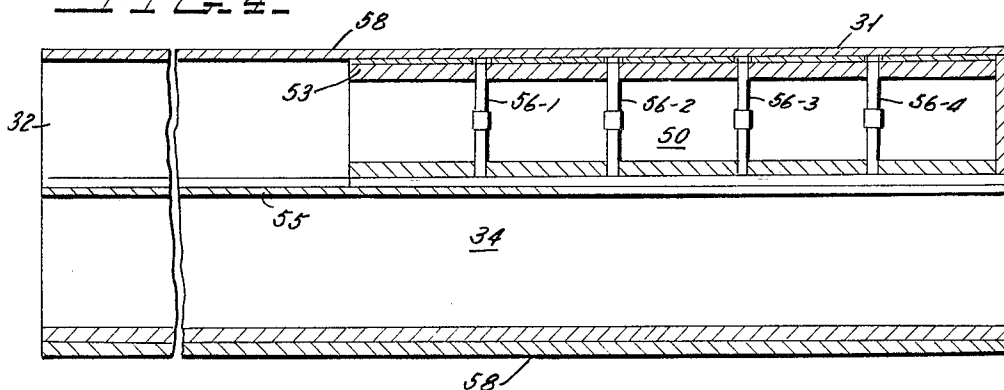


FIG. 4A

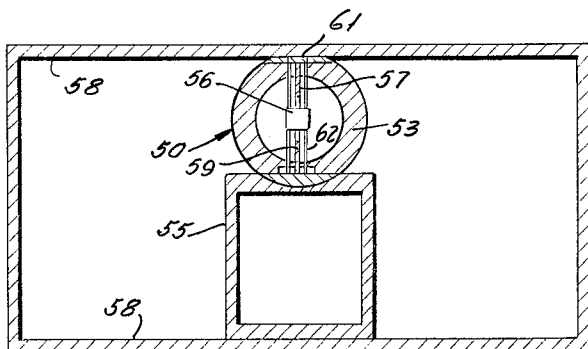


FIG. 5

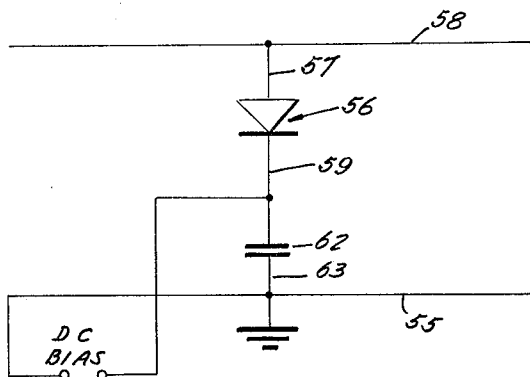
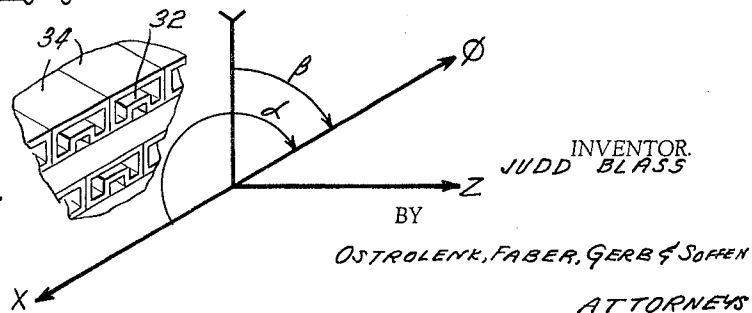


FIG. 6



Sept. 20, 1966

J. BLASS

3,274,601

ANTENNA SYSTEM WITH ELECTRONIC SCANNING MEANS

Filed Dec. 12, 1962

5 Sheets-Sheet 4

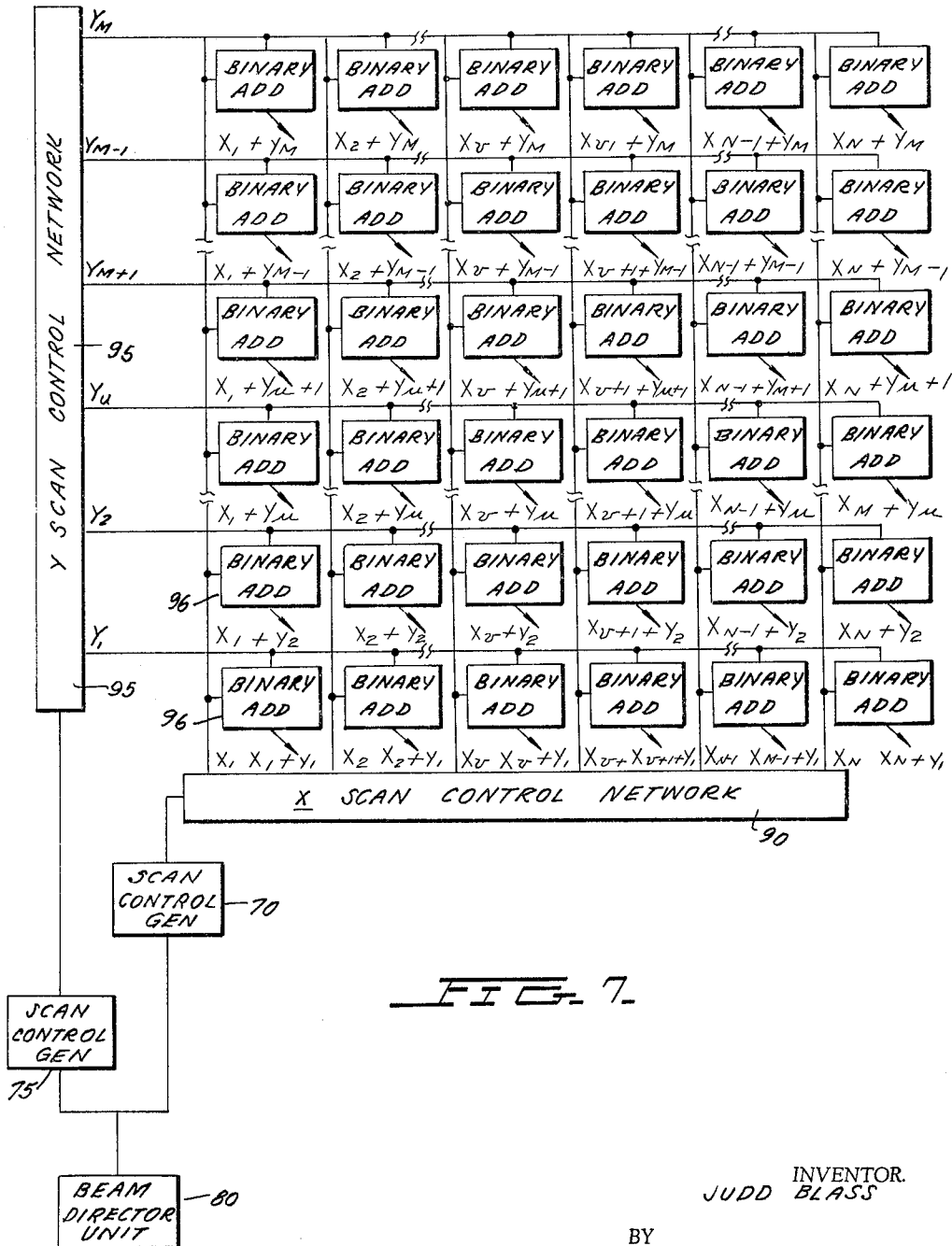


FIG. 7.

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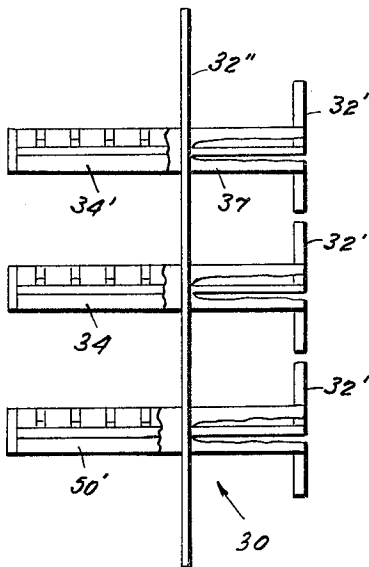
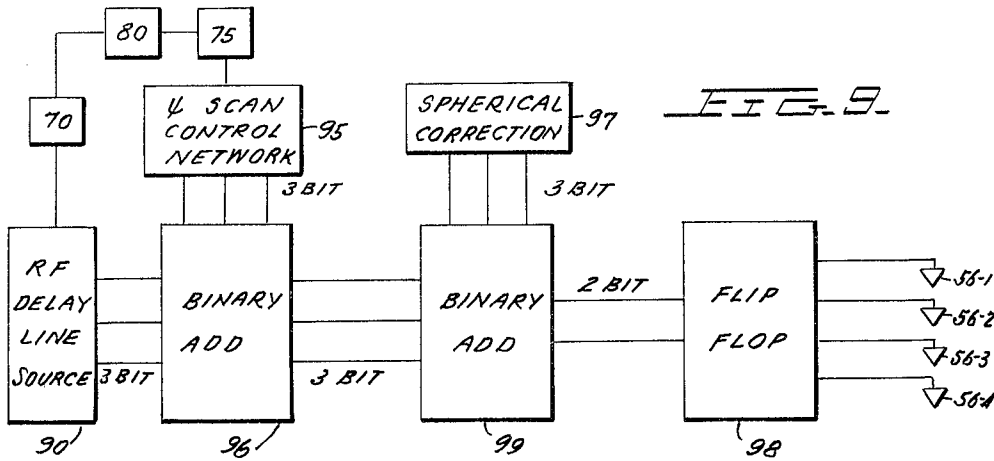
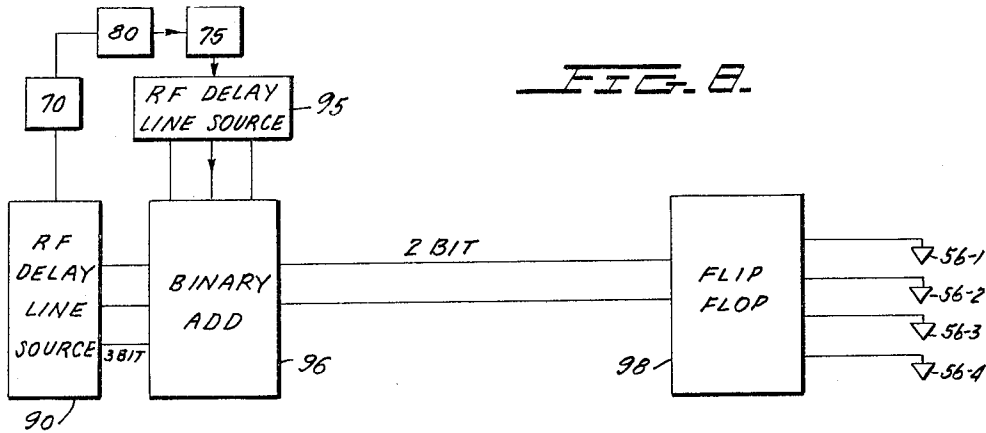
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ANTENNA SYSTEM WITH ELECTRONIC SCANNING MEANS

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5 Sheets-Sheet 5



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1

3,274,601

ANTENNA SYSTEM WITH ELECTRONIC SCANNING MEANS

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Filed Dec. 12, 1962, Ser. No. 244,089

17 Claims. (Cl. 343-754)

This invention relates to antenna systems and more particularly to a technique for scanning the beam of a reflective antenna system without physically moving either the reflector or feed. Such scanning is obtained in a preferable manner by the cooperation of the signal feed with a novel reflecting surface formed of a plurality of inter-related radiating elements. The phase of the signals established by individual ones of the radiating elements may be rapidly switched to cause the contour of the reflecting surface to electrically vary, thereby effecting scanning of the antenna beam through a sector in space.

Directive antennas are used in a variety of narrow beam systems, such as conventional radar installations, to accurately determine the angular position of a target under investigation. Such systems generally must include a means for positioning a narrow beam of energy about a much wider scan angle in space. One well known method for obtaining antenna beam scanning is to move the reflector mount structure itself to appropriately direct the secondary beam in the desired direction. Another technique utilizes a feed horn slightly off center with respect to the principal axis of a parabolic reflector. The feed horn is then physically moved about a small area concentric with the focus of the reflector. Such movement of the feed horn similarly rotates the axis of directivity of the secondary beam. Because of system inertia and other mechanical difficulties encountered with movement of the reflector or feed itself, such prior art systems have been severely limited as to scanning rates and accuracy.

Other prior art arrangements have been formed of various arrays of individual amplifier and radiating element pairs, electrically connected by separate transmission lines. The energy fed to each of the radiating elements is judiciously phase adjusted to have a uniform phase variation between adjacent elements. If the phase is made to progressively differ along the array, the energy maximum will not occur in the direction of the principal axis, but rather at some angle with respect thereto. Accordingly, the direction of major response of the antenna can be swept across a sector of space by proper variation of the phase between the individual radiating elements of the array. Such systems have typically been quite complex, space consuming and have exhibited severe limitations as to scan angle rate, switching techniques and energy loss.

Another method of scanning a beam utilizes a line source of energy which is capable of having a uniform phase variation along its length. Such a phase variation may be obtained by relative movement of the feed source members, with one such arrangement utilizing a rotating or oscillating prism intermediate the line source and the radiators. Another linear array arrangement has been obtained by mechanically varying the path lengths along a line source beam, as employed in the well known Foster scanner (shown in U.S. Patent No. 2,832,936). Other linear array scanning systems have been constructed to vary the phase between slots along a wave guide or coaxial line by reciprocating motion of the waveguide walls or rotation of a specially constructed linear coaxial conductor. Besides exhibiting the aforementioned mechanical difficulties, such previously practiced linear arrays have demonstrated high mismatch, loss in gain, and limitation as to possible scan angles and beam focussing capabilities.

2

A preferred linear array system may be constructed in the manner shown in my copending U.S. patent application (M-877) entitled "Antenna System," Serial No. 230,358, filed Oct. 15, 1962. That patent application shows a simplified arrangement of parallel fed radiating elements coupled to a main signal channel in the manner of a traveling wave array, with the individual path lengths between the main signal feed and the individual radiators electrically variable in an extremely simple manner, to point a narrow beam of energy in a desired direction. Such a system, however, will still exhibit beam focusing limitations.

My invention avoids the limitations of the prior art systems by the utilization of a novel concentrating reflector in conjunction with a signal feed located at the focal region thereof. The reflecting surface is formed of a plurality of individual phase controlled radiating elements operating in the manner of a phased backscatter array. The relative phase of individual wave signals formed at the reflecting surface are individually and rapidly controllable in a simplified manner (as, for example, in the order of a few nano-seconds (10^{-9} seconds)) to electrically analogize the reflecting surface and signal feed to a conventional parabolic system scanned to the desired direction. That is, the phase control circuitry associated with the individual radiating elements additively changes the electrical contour of the reflecting surface to reposition its axis of directivity. Thus, my invention permits the scanning of a concentrated beam formed by the cooperation of a reflecting surface and a signal feed, without requiring physical movement of either the feed or the reflecting surface. Further, the focal point is not restricted by the geometry of the system, but may be arbitrarily located.

In a preferred embodiment of my invention the reflecting surface is formed of a plurality of individual radiating elements, such as open-ended ridge waveguides, arranged about a planar area to form a rectangular matrix; the matrix being referable to orthogonally related axes. Each of the radiating elements is electrically connected to individual, but electrically associated wave channels of a novel phase shift network. The novel phase shift network comprises separate branch signal channels, such as ridged waveguides, for each of the radiating elements. The radiating elements are at one end region of the branch signal channels and an adjustable microwave short at the other end region.

The radiating elements forming the reflecting surface can be of any number or type (e.g. small horns flush mounted dipoles), consistent with the requirements of the radiating apertures. The design of these elements and their location about the antenna apertures region is carefully chosen so as to maximize the capture efficiency and minimize the energy which is lost as direct reflections or scatter. As for example, I have obtained particularly favorable results from spacing the individually radiating elements approximately $\frac{1}{2}$ wavelength apart at the mean frequency of operation.

Although for purposes of explanation, the ensuing discussion is principally directed to the transmit mode of operation, it is to be understood that an analogous condition prevails for receiver operation. Hence, the antenna system of my invention is equally adaptable for both the transmit and receive mode.

The wave signal energy of each branch signal channel which is originally incident on their respective radiating elements is first directed backwards along the length of the branch signal channel until it encounters the microwave short circuit at the second end region. The signal is then oppositely directed back towards the first end region, wherein it is propagated into space by the radiating element. The microwave short circuit is longitudinally

adjustable along the second end region of the branch signal channel, such that the path length traveled by each of the wave signals is independently adjustable. The phase of the wave signal reflected back to the radiating element will accordingly be determined by the above described path length traversed. Hence, the repositioning of the shorting element along the second end region of the branch signal channel will accordingly introduce a phase shift adjustment in the wave signal propagated by its associated radiating element.

In a practical antenna built in accordance with my invention, it is oftentimes desirable to include a great number of individually controllable radiating elements (which may be up to or in excess of 10,000). A particularly advantageous aspect of my invention is the simplified manner in which I provide individual adjustment of such a large number of branch circuit shorting elements. Whereas the phased arrays of the prior art typically must include rather expensive and complex arrangements to effect the proper phase differential between the adjacent radiating elements, my invention preferably provides such variation by the digital control of switching diodes. The diodes are digitally switched in a simplified and inexpensive manner into their conducting or blocking states, the former effecting a short circuit condition across the branch signal guides. I have observed that proper programming of only four such shorting diodes in each branch signal channel is adequate to obtain a sharply defined and accurately positioned beam. Such a four diode adjustable short permits a substantial simplification in the manner in which the individual path lengths may be varied to obtain the requisite progressive phase shift for beam scanning. A two bit flip flop circuit is advantageously employed as the phase adjusting means, with the flip flop outputs connected to the shorting diodes to provide the necessary bias potential for switching. Hence, my switching technique preferably avoids the use of multiple receivers, transmitters or ferrite phase shifters as typically employed in the phased array systems of the prior art.

As another aspect of my invention, the orthogonal matrix of the individual radiating elements permits a substantial simplification in the generation of the scan control signals. It is well known in the art that the phase distribution of such a planar array whose individual elements are arranged in a rectangular matrix can be separated as the sum of two independent phase distributions corresponding to the orthogonal axes of the array. Accordingly, where a large number of individual radiating elements are to be used, the scan control generator referable to each axis need only provide the square root of the number of phasing signals as there are radiating elements. These signals are fed to binary add circuits individual to each adjustable short. The binary adding circuits as well as the flip flops are commercially available in relatively inexpensive, highly compact and extremely reliable assemblies, to thereby provide trouble free operation.

For increased accuracy the orthogonally related scan control signals presented to the inputs of the binary add circuit are advantageously three-bit digital signals. Each of the diodes are positioned to effect an overall 90° phase differential in the path length. Hence, digital outputs of the add circuit which correspond to fractions of a 90° differential or to multiples of a 360° differential may be dropped. Accordingly, the sum of the three-bit digital signals need only be transposed as a two-bit signal, which signals additively effect an accurate positioning of the antenna system beam. As a further refinement, a spherical correction factor may be interposed intermediate the scan control signal generator and the binary add circuit which presents the two-bit digital signal to the flip flop control of the shorting diodes. Particularly advantageous operation is obtained by employing a digital scan control system for switching the adjustment means of the four position diode shorts. That is, in previous systems employing

analog control networks the presence of noise or other extraneous signals within the system resulted in an inaccuracy in the beam position, thereby limiting its application for high precision lobing. By properly designing the flip flop switches of my control system, such extraneous signals will be below the threshold switching level. Thus, they will have substantially no effect on the digital output signal, and therefore will not cause an improper positioning of the scan angle.

It is thus seen that the basic concept of my invention resides in forming the reflecting surface of an antenna system of a plurality of radiating elements, each associated with an individual branch signal channel. The branch signal channels include an adjustable short to vary the phase of their respective signals at the reflecting surface. The reflecting shorts of the individual branch signal channels may be rapidly switched to provide for rapid and accurate scanning of the focused antenna beam formed by the additive effect of the branch signals.

It is therefore a primary object of this invention to provide a simplified, rapid and accurate reflective antenna scan system.

A further object of this invention is to provide an antenna scan system wherein the reflecting surface operates in the manner of a conventional parabolic reflector in conjunction with a signal feed at the focal region thereof, which may be electrically scanned without physical movement of either the reflector or the signal feed.

Another object of this invention is to provide an antenna scan system having a reflecting surface formed of a predetermined array of individual radiating elements, each electrically associated with an individual wave signal channel having an adjustable short at the opposite end thereof.

An additional object of this invention is to provide such an antenna system wherein the adjustable short is electrically controlled such that the additive phase effect of the radiating element signals will controllably position the antenna beam in a desired direction.

Still a further object of this invention is to provide such a reflective antenna system wherein the shorting elements are rapidly adjustable to modify the phase of the emergent signal such that the scan angle determined by the additive phase effect of the individual radiating elements produces a concentrated beam of energy adjustable in direction.

Still another object of this invention is to provide a reflective antenna scanning system wherein the reflecting surface is formed of a matrix array of individual radiating elements, the phase of each of the signals established by the radiating elements being controllable by orthogonally related digital signals.

Still an additional object of this invention is to provide a reflective antenna system including controllable signal reflecting means formed of individual shorting diodes, bias switched between their conducting and non-conducting states by the output potential of a two-bit digital circuit to provide beam scanning.

These as well as other objects of the instant invention will readily become apparent after reading the following description of the accompanying drawings in which:

FIGURE 1 is a perspective view of an antenna system constructed in accordance with the teachings of my invention.

FIGURE 2 is a partially broken away perspective view of a portion of the reflecting surface, showing the adjacent positioning of the radiating elements, the branch signal wave guides, and the adjustable reflecting means.

FIGURE 3 is a simplified schematic illustration showing the basic operation of the phase shift adjust of each of the branch signal channels.

FIGURES 4 and 4a are end and cross-sectional views respectively of a shorting diode array which may be used in conjunction with my invention.

FIGURE 5 is a simplified schematic representation of the operation of an individual diode shorting element.

FIGURE 6 schematically shows the spaced relationship between the antenna beam orientation and the orthogonally related axes of the radiating element array.

FIGURE 7 is a block diagram illustrating the matrix arrangement of the scanning generator and the individual binary add circuits of the adjustment control means.

FIGURE 8 is a block diagram showing the interrelationship of the scan control generator, the binary add circuit, the switching flip flop and the individual diode switches.

FIGURE 9 is a block diagram similar to FIGURE 8, but showing the addition of a means for spherical correction.

FIGURE 10 shows an alternative embodiment of the radiating elements, which are shown as comprising individual dipoles.

FIGURES 11 and 12 are plan and elevation views respectively of a phase back scatter array antenna system constructed in accordance with the teachings of my invention, which utilizes three independent reflecting surfaces and signal feeds for hemispheric scan coverage.

Referring to the figures and FIGURES 1 and 2 particularly, antenna system 20 comprises a reflecting surface 30 and a signal feed 40. Reflecting surface 30 is formed of a plurality of adjacently positioned radiating elements 32 forming a generally planar surface mounted to stationary platform 48. Feed 40 is appropriately secured to the reflecting surface by side supports 42. Transmission line 44 interconnects feed 40 to a receiver or transmitter (not shown), to effect operation in either the transmit or receive mode. Radiating elements 32 are typically shown as open end ridge wave guides. Alternatively the radiating elements may be small horns or dipoles constructed to be electrically consistent with the requirements of the particular antenna system. In the particular example shown in FIGURES 1 and 2, they are open ended ridge wave guides having a center to center separation approximately one-half wavelength at the mean operating frequency. Each of the radiating elements 32 are located at a first end region of an individual branch signal channel 34, such branch signal channel being illustratively shown as a ridged waveguide. The phase of the individual branch signals at 32 are individually varied by an adjustable reflecting means generally shown at 50, one form of which is shown in FIGURES 4 and 5. The radiating elements 32 are positioned such that the phase of the individual signals associated therewith may be progressively shifted by beam director unit 80, in the manner to be subsequently discussed, to electrically form a parabolic surface at 32 in conjunction with feed 40. Pin 33 is shown for improved impedance matching. Fiber glass radome 35 may also be included for environmental protection.

As is well known in the art, the direction of a beam generated by such an array of individual radiating elements 32 is determined by the phase correspondence of the individual signals; that is, the scan angle of the antenna beam will be in that direction which corresponds to phase coincidence of the individual radiating elements. Accordingly, by proper control of the phase of each of the signals associated with the individual radiating elements 32, an additive effect is obtained, such additive effect being controlled to provide scanning of the concentrated antenna beam. Such control is obtained by sequentially related digital signals of a beam director unit 80, which signals are shown presented by harness runs 60 to the individual adjustable reflecting means 50. Signal feed 40 is appropriately designed to illuminate the surface 30 with a minimum of spillover. Thus, the wave signal provided by feed 40 is picked up by radiating element 32 and directed towards its opposite end region of branch wave signal channel 34. If channel 34 were terminated in a matched load, the power dissipated by

such a load would exactly equal the power re-radiated by the parasitic current associated with radiating element 32. The radiation pattern of such parasitic currents would be the image of the incident wave, and hence exhibit limited directivity. However, if branch signal channel 34 is short-circuited at 50, the signal which travels down the line will be reflected at such short circuit, and directed back towards radiating element 32, where it is radiated into space. Thus, in the short circuited case, the radiation field consists of the parasitic current plus the back scatter radiation from the current which travels down, to, and back from the reflecting means; the phase of the back scatter component being equal to twice the electrical length from the radiating element 32 to the short circuit. In accordance with my invention a progressive phase shift is obtainable between adjacent radiating elements by proper adjustment of the short circuit positions to therefore collimate the individual branch wave signals into a pencilled beam. The additive phase effect of the beam is steerable in space by appropriate adjustment of the reflecting means.

Reference is now made to FIGURE 3, which shows in a simplified manner the basic operation of the phase shift adjust provided by the reflecting means 50 in each of the branch signal channels 34. The operation of only one such channel is shown with it being understood that an analogous mode of operation is obtained in each of the other channels. End 31 of the branch wave signal channel includes an adjustable reflective short 50 which is preferably shown as a longitudinally positioned array of individual diode elements 56. It is to be noted that these short circuits need not be diodes or be discreet. Alternatively, these elements may be any other device well known in the art to provide an adjustable reflecting surface, such as a sliding metal shorting plunger. However, the diode arrangement shown preferably permits a switching arrangement in a more simplified and rapid manner than has heretofore been available, permitting optimum electronic performance. Four such diode elements 56-1 to 56-4 are shown which may be appropriately switched between their conducting and blocking states to selectively position the short within each of the branch channels. Incident energy A, upon reaching the shorted diode, illustratively shown as 56-3, is reflected and directed back towards end 32, as shown by arrow B (shown dotted for purposes of clarity). The phase of reflected wave B is accordingly dependent upon which of the individual diodes is shorted. Inasmuch as the signal within the branch signal channel traverses a path in an up-and-down direction towards short 50, each of the diode elements 56 are separated by one-eighth of a wavelength at the mean operating frequency of the antenna system, to provide a one-quarter wavelength overall path differential to the branch waveguide signal.

FIGURES 4, 4A and 5 illustrate a preferred configuration and schematic representation of the diode shorting elements 56. All of the elements 56 of a shorting switch array 50 are disposed within a longitudinal dielectric tube 53 to facilitate insertion and removal of the switching array as a unit intermediate waveguide walls 58 and ridge 55. The waveguide walls and ridge 55 are at ground potential. The anode terminal 57 of diode element 56 is shown connected to one of the wall surfaces via metallic insert 61 in the dielectric tube. The cathode terminal 59 of the diode is connected to a positive D.C. bias, which may typically be one of the outputs of flip flop control 98 (FIGURE 8). The D.C. bias presented by the flip flop output to the cathode 59 is of a sufficient magnitude to place the diode in its blocking state, thereby providing an open circuit. Removal of the D.C. bias places diode 56 in its conducting state, thereby providing a reflective short to the incident microwave signal. Capacitive element 62 is provided for RF bypass of the bias return 63. It is thus seen that the individual diodes 56 are conveniently contained within a compact unitary structure which may be

easily inserted and properly positioned within the end region 31 of the individual branch wave channels.

Reference is now made to FIGURE 6 which shows the relative orientation between the radiating elements 32 and the beam direction ϕ . Radiating elements 32 are shown adjacently positioned to form a rectangular matrix in the plane defined by orthogonally related axes x and y . It is well known that the phase distribution of a planar antenna whose elements are arranged in a rectangular matrix as shown in FIGURE 6 can be separated as the sum of two independent phase distributions, each varying according to the cosine of the angles from the orthogonally related axes (α and β). Accordingly, FIGURE 7 illustrates such a matrix wherein beam director unit 80 presents appropriate signals to the x and y scan control generators 70, 75 respectively. The output signals of the scan control generators 70, 75 are presented to x and y scan control networks 90, 95 respectively. These networks may typically be an arrangement of conventional digital circuitry to provide properly phase delayed signals along the x and y axes. Alternatively, $a-f$ delay line networks may be used to phase control the individual branch signal waves to cumulatively yield the desired scan angle. The output signals of the scan control networks 90, 95 are presented as input signals to binary add circuits 96, each located at the x - y intersection of their corresponding radiating elements 32. The binary add output signals will accordingly be correlated to position the antenna beam in the desired direction ϕ .

Referring to FIGURE 8, the signal provided by x and y scan control generators 70, 75 to the binary add circuit 96 is preferably a three-digit signal. Such a three-digit signal provides additional precision of the sum signal presented by add circuit 96 to flip flop 98. The sum signal output of the binary add circuit 96 may, however, drop those digits corresponding to integral multiples of a wavelength and less than a quarter wavelength variation. Hence, the sum obtained by adding the three-digit input signals may be transposed to a two-digit signal for operation of the four position shorting diode array 56-1 to 56-4.

In a typical case the input signals presented by each of the scan control networks 70, 75 do not correspond to exact multiples of the quarter wave delay obtainable by the four position shorting switch. Thus, where an intermediate amplitude signal is presented, the phase shift of its associated branch signal circuit might not exactly correspond to that theoretically required for a desired scan angle. However, it has been found that by providing a sufficient number of branch channels and associated radiating elements in the overall antenna system, the cumulative effect of these slight deviations tend to cancel, thereby giving a scan angle accurately related to the signal generated by beam director unit 80.

Referring to FIGURE 9 it is seen that an additional digitally controlled signal 97 may be provided intermediate binary add circuit 96 and flip flop 98, to provide appropriate spherical correction. Signal 97 is presented as one input to an intermediate binary add circuit 99, which circuit receives a three-bit output sum signal from binary add circuit 96 as its other input. Hence, the system schematically shown in FIGURE 9 provides beam scanning in conjunction with a tunable spherical correction factor.

Digital control of the individual branch signal phase shift is preferably used to reduce the susceptibility of antenna system 20 to errors caused by the generation of noise or other extraneous signals within the circuitry. That is, the circuitry can be appropriately designed such that the digital switching amplitude is kept substantially above any such extraneous signal. Therefore, the presence of these signals will not have an effect on the output count of flip flops 98 and hence the phase shift of the individual branch circuits 34. This permits extreme accuracy in the beam position and affords my invention particular utility for high precision, high frequency lobing.

FIGURE 10 shows a modified arrangement of the radiating elements 32' which comprise the reflecting surface 30'. These elements are shown as balanced dipoles connected to branch wave signal channels 34' formed of coaxial transmission lines. Appropriate impedance transformer sections 37, such as a Balun-dipole to coaxial line transformer, are interposed intermediate the radiating dipole 32 and the coaxial line 34'. A reflecting ground screen 32'' operates in conjunction with the individual dipoles 32' and is preferably located a quarter wavelength therefrom. Short circuit elements 50' are of the same general type discussed above with appropriate dimensional changes to permit their use in conjunction with the coaxial line 34'. The feed horn, antenna structure and scan control used in conjunction with this embodiment may be the same as discussed above since these system components are essentially independent of the array element and its transmission line accessories.

Reference is now made to FIGURES 11, 12, which show three separate antenna systems 20-1, 20-2 and 20-3, each generally of type 20 discussed above. Each of the systems contain a reflecting surface 30-1, 30-2, 30-3 respectively, operating in conjunction with respective signal feeds 40-1, 40-2, 40-3. The use of three such independent antennas may be appropriately correlated to provide hemispheric scan coverage.

It is thus seen that I have provided a novel antenna system whereby a concentrated antenna beam formed by a parabolic type reflecting surface and signal feed may be appropriately scanned without physical movement of the antenna feed or reflecting surface. Accordingly, the focal points can be arbitrarily fixed and are not restricted by the geometry of the antenna, as is the case of a simple reflector or lens. Further, several signal feeds at different locations may be used in conjunction with a signal reflecting surface to provide increased performance capabilities.

A practical antenna system constructed in accordance with the teachings of my invention may be, for example, constructed to operate within the frequency range of 2800 megacycles to 3400 megacycles, having a $2\frac{1}{2}^\circ$ beam width rapidly adjustable within a 120° sector in all planes. It is possible to obtain 33 db of gain with the side lobes being maintained below 20 db. It is naturally understood that these operating characteristics are merely given for illustrative purposes and should not be construed as limiting the scope of my invention. Accordingly, although I have described preferred embodiments of my novel invention, many variations and modifications will now be obvious to those skilled in the art, and I prefer therefore to be limited not by the specific disclosure herein but only by the appended claims.

The embodiments of the invention in which an exclusive privilege or property is claimed are defined as follows:

1. In combination in an antenna system, a reflecting surface and a signal feed; scanning means cooperatively associating said reflecting surface with respect to said signal feed to effect an antenna beam orientation in a desired direction; said reflecting surface formed of a plurality of radiating elements, each associated with a branch signal channel; said radiating elements operatively positioned with respect to said signal feed to present a plurality of branch wave signals therebetween; said radiating elements positioned at a first end region of said branch signal channels; individual signal reflecting means at a second end region of each of said branch signal channels; said branch wave signals traversing a path from said radiating elements at said first end region, towards said second end region, and from said reflecting means at said second end region oppositely directed back toward said first end region; adjusting means individually controlling the characteristics of said plurality of reflecting means whereby the phase of said branch wave signals at each of said first end regions may be individually varied; the additive phase effect of said branch wave signals es-

establishing said desired direction of antenna beam orientation, said reflecting means including shorting means, said adjustment means selectively positioning said shorting means along the second end region of said branch signal channels, whereby the overall lengths of selected ones of said branch signal paths are varied.

2. In combination in an antenna system, a reflecting surface and a signal feed; scanning means cooperatively associating said reflecting surface with respect to said signal feed to effect an antenna beam orientation in a desired direction; said reflecting surface formed of a plurality of radiating elements, each associated with a branch signal channel; said radiating elements operatively positioned with respect to said signal feed to present a plurality of branch wave signals therebetween; said radiating elements positioned at a first end region of said branch signal channels; individual signal reflecting means at a second end region of each of said branch signal channels; said branch wave signals traversing a path from said radiating elements at said first end region, towards said second end region, and from said reflecting means at said second end region oppositely directed back toward said first end region; adjusting means individually controlling the characteristics of said plurality of reflecting means whereby the phase of said branch wave signals at each of said first end regions may be individually varied; the additive phase effect of said branch wave signals establishing said desired direction of antenna beam orientation, said reflecting means including shorting means, said adjustment means selectively positioning said shorting means along the second end region of said branch signal channels, whereby the overall lengths of selected ones of said branch signal paths are varied; said reflecting means comprising a group of diodes positioned along the second end region of said branch signal channel; each of said diodes having a conducting and a blocking state; said diodes when in said conducting state providing a reflective short to said couple energy; said adjustment means presenting a biasing signal to said diode elements whereby switching said diode elements between said conducting and said blocking states.

3. In combination in an antenna system, a reflecting surface and a signal feed; scanning means cooperatively associating said reflecting surface with respect to said signal feed to effect an antenna beam orientation in a desired direction; said reflecting surface formed of a plurality of radiating elements, each associated with a branch signal channel; said radiating elements operatively positioned with respect to said signal feed to present a plurality of branch wave signals therebetween; said radiating elements positioned at a first end region of said branch signal channels; individual signal reflecting means at a second end region of each of said branch signal channels; said branch wave signals traversing a path from said radiating elements at said first end region, towards said second end region, and from said reflecting means at said second end region oppositely directed back toward said first end region; adjusting means individually controlling the characteristics of said plurality of reflecting means whereby the phase of said branch wave signals at each of said first end regions may be individually varied; the additive phase effect of said branch wave signals establishing a reflective antenna system having a focal point at said signal feed corresponding to said desired direction of antenna beam orientation, said reflecting means including shorting means; said adjustment means selectively positioning said shorting means along the second end region of said branch signal channels, whereby the overall lengths of selected ones of said branch signal paths are varied.

4. The antenna system of claim 1 wherein said shorting means include a plurality of individual shorting elements longitudinally separated along the second end region of said branch signal channel.

5. The antenna system of claim 3 wherein said shorting means comprise diodes placed across said branch sig-

nal channel, and longitudinally separated to introduce a predetermined path differential of said branch signal.

6. The antenna system of claim 3 wherein said adjustment means presents a biasing signal to selected ones of said diodes; said biasing signal switching said diodes between their conducting and blocking states.

7. The antenna system of claim 2 wherein each of said branch channels include four of said diode elements; said adjustment means being a two-bit digital circuit; the output signals of said digital circuits providing the switching bias of said diode elements.

8. The antenna system of claim 7 further including a scan control means; said scan control means presenting sequentially related digital control signals to said adjustment means, whereby said diode elements are selectively adjusted to control the scan angle of said antenna beam.

9. In combination in an antenna system, a reflecting surface and a signal feed; scanning means cooperatively associating said reflecting surface with respect to said signal feed to effect an antenna beam orientation in a desired direction; said reflecting surface formed of a plurality of radiating elements, each associated with a branch signal channel; said radiating elements operatively positioned with respect to said signal feed to present a plurality of branch wave signals therebetween; said radiating elements positioned at a first end region of said branch signal channels; individual signal reflecting means at a second end region of each of said branch signal channels; said branch wave signals traversing a path from said radiating elements at said first end region, towards said second end region, and from said reflecting means at said second end region oppositely directed back toward said first end region; adjusting means individually controlling the characteristics of said plurality of reflecting means whereby the phase of said branch wave signals at each of said first end regions may be individually varied; the additive phase effect of said branch wave signals establishing said desired direction of antenna beam orientation; said reflecting means including shorting means; said shorting means comprising a group of diodes positioned along the second end region of said branch signal channel; each of said diodes having a conducting and a blocking state; said diodes when in said conducting state providing a reflective short to said couple energy; said adjustment means presenting a biasing signal to said diode elements whereby switching said diode elements between said conducting and said blocking states; said radiating elements forming a matrix defined by orthogonally related axes, the location of each of said radiating elements being referable to the origin of said orthogonally related axes; scan control means associated with each of said orthogonally related axis to present sequentially related digital control signals to said adjustment means.

10. The antenna system of claim 9, wherein said adjustment means includes a binary adding circuit; the sequentially related signals of said scan control means being presented to the input of said binary adding circuit as orthogonally related components; the output of said binary adding circuit forming said biasing signals for diode switching, whereby said diode elements are selectively adjusted to control the scan angle of said antenna beam.

11. The antenna system of claim 9, wherein said adjustment means includes a binary adding circuit; the sequentially related signals of said scan control means being presented to the input of said binary adding circuit as orthogonally related components; the output of said binary adding circuit forming said biasing signals for diode switching, whereby said diode elements are selectively adjusted to control the scan angle of said antenna beam; said selective adjustment of diode elements forming said reflecting surface in the manner of a parabolic reflector with respect to said signal feed; said signal feed being operatively located at the focal point of said parabolic reflecting surface.

12. The antenna system of claim 11 wherein said scan control means operatively switches said diode element to controllably vary the additive phase effect of said branch wave signals, to thereby vary the antenna beam orientation of said parabolic reflector and cooperating signal feed.

13. A scanning antenna system including a signal feed and a reflecting surface; said reflecting surface formed of a plurality of radiating elements; said radiating elements operatively positioned with respect to said signal feed to present a wave signal therebetween; a plurality of branch signal channels; said radiating elements positioned at a first end region of said branch signal channels; said first end regions collectively defining said reflecting surface; a second end region of said branch signal channels including a signal reflecting means; said wave signal forming a plurality of branch wave signals; said branch wave signals traversing a path within said branch signal channels from said radiating elements towards said reflecting means, and from said reflecting means oppositely directed towards said first end region; adjustment means individually controlling the characteristics of each of said reflecting means whereby the phase of said branch wave signal at each of said first end regions may be individually varied; said radiating elements adjacently located in a first and second direction to define a generally planar region of said reflecting surface; said signal feed positioned without said generally planar region, and in a wave signal illuminating relationship therewith; the additive phase effect of said branch wave signals establishing an antenna beam orientation with respect to said signal feed in the manner of a parabolic reflector; said radiating elements forming a matrix defined by orthogonally related axes; the location of each of said radiating elements being referable to the origin of said orthogonally related axes; scan control means associated with each of said orthogonally related axes to present sequentially related digital control signals to said adjustment means.

14. A scanning antenna system including a signal feed and a reflecting surface; said reflecting surface formed of a plurality of radiating elements; said radiating elements operatively positioned with respect to said signal feed to present a wave signal therebetween; a plurality of branch signal channels; said radiating elements positioned at a first end region of said branch signal channels; a second end region of said branch signal channels including a signal reflecting means; said wave signal forming a plurality of branch wave signals; said branch wave signals traversing a path from said radiating elements towards said reflecting means, and from said reflecting means oppositely directed towards said first end region; adjustment means individually controlling the characteristics of each of said reflecting means whereby the phase of said branch wave signal at each of said first end regions may be individually varied; said radiating elements adjacently located in a first and second direction to define a generally planar region of said reflecting surface; said signal feed positioned without said generally planar region, and in a wave signal illuminating relationship therewith; the additive phase effect of said branch wave signals establishing an antenna beam orientation with respect to said signal feed in the manner of a parabolic reflector; said radiating elements forming a matrix defined by orthogonally related axes; the location of each of said radiating elements being referable to the origin of said orthogonally related axes; scan control means associated with each of said orthogonally

nally related axes to present sequentially related digital control signals to said adjustment means; said adjustment means includes a binary adding circuit; the sequentially related signals of said scan control means being presented to the input of said binary adding circuit as orthogonally related components; the output of said binary adding circuit forming said biasing signals for diode switching, whereby said diode elements are selectively adjusted to control the scan angle of said antenna beam.

15. A scanning antenna system including a signal feed and a reflecting surface; said reflecting surface formed of a plurality of radiating elements; said radiating elements operatively positioned with respect to said signal feed to present a wave signal therebetween; a plurality of branch signal channels; said radiating elements positioned at a first end region of said branch signal channels; said first end regions collectively defining said reflecting surface; a second end region of said branch signal channels including a signal reflecting means; said wave signal forming a plurality of branch wave signals; said branch wave signals traversing a path within said branch signal channels from said radiating elements towards said reflecting means, and from said reflecting means oppositely directed towards said first end region; adjustment means individually controlling the characteristics of each of said reflecting means whereby the phase of said branch wave signal at each of said first end regions may be individually varied; said radiating elements adjacently located in a first and second direction to define a generally planar region of said reflecting surface and collectively defining said reflecting surface; said signal feed positioned without said generally planar region, and in a wave signal illuminating relationship therewith; the additive phase effect of said branch wave signals establishing an antenna beam orientation with respect to said signal feed in the manner of a parabolic reflector; said reflecting means including shorting means, said adjustment means selectively positioning said shorting means along the second end region of said branch signal channels, whereby the overall lengths of selected ones of said branch signal paths are varied.

16. The scanning antenna system of claim 15, wherein said reflecting means comprises a group of diodes positioned along the second end region of said branch signal channel; each of said diodes having a conducting and a blocking state; said diodes when in said conducting state providing a reflective short to said couple energy; said adjustment means presenting a biasing signal to said diode elements whereby switching said diode elements between said conducting and said blocking states.

17. The antenna system of claim 10 wherein each of said branch signal channels include four of said diode elements; said scan control means present orthogonally related three-bit digital signals to the input of said binary adding circuit; the output signal of said binary adding circuit being converted to a two-bit digital signal providing the switching bias of said diode elements.

References Cited by the Examiner

FOREIGN PATENTS

860,826 2/1961 Great Britain.

HERMAN KARL SAALBACH, *Primary Examiner.*

R. H. HUNT, *Assistant Examiner.*