

[54] SPACE FEED RECEIVER ARRAY 3,568,184 2/1971 Drabowitch 343/854

[75] Inventors: Dietrich A. Alsberg, Berkeley Heights; Raymond D. Tuminaro, Livingston, both of N.J.

[73] Assignee: The United States of America as represented by the Secretary of the Army, Washington, D.C.

[22] Filed: Aug. 28, 1974

[21] Appl. No.: 501,406

[52] U.S. Cl. 343/754; 343/100 SA; 343/778; 343/854; 343/911 L

[51] Int. Cl.² H01Q 3/26

[58] Field of Search 343/754, 854, 100 SA, 778, 343/911 L

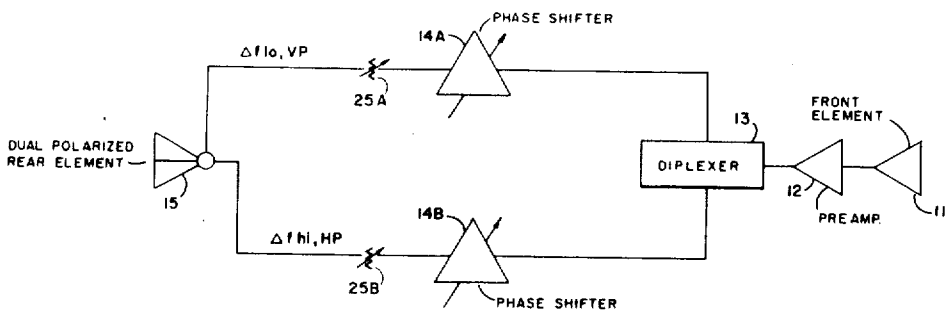
Primary Examiner—Eli Lieberman
Attorney, Agent, or Firm—Lawrence A. Neureither;
Joseph H. Beumer; Robert C. Sims

[57] ABSTRACT

A space feed phased array receiver system provides independent steering of discrimination and tracking clusters in the space feed by dividing each antenna cartridge into two channels. Each channel operates over a different portion of the RF band; each radiates a different sense of polarization to the focal region; and each is independently steered.

[56] References Cited
UNITED STATES PATENTS
3,496,569 2/1970 Alsberg et al. 343/754

6 Claims, 10 Drawing Figures



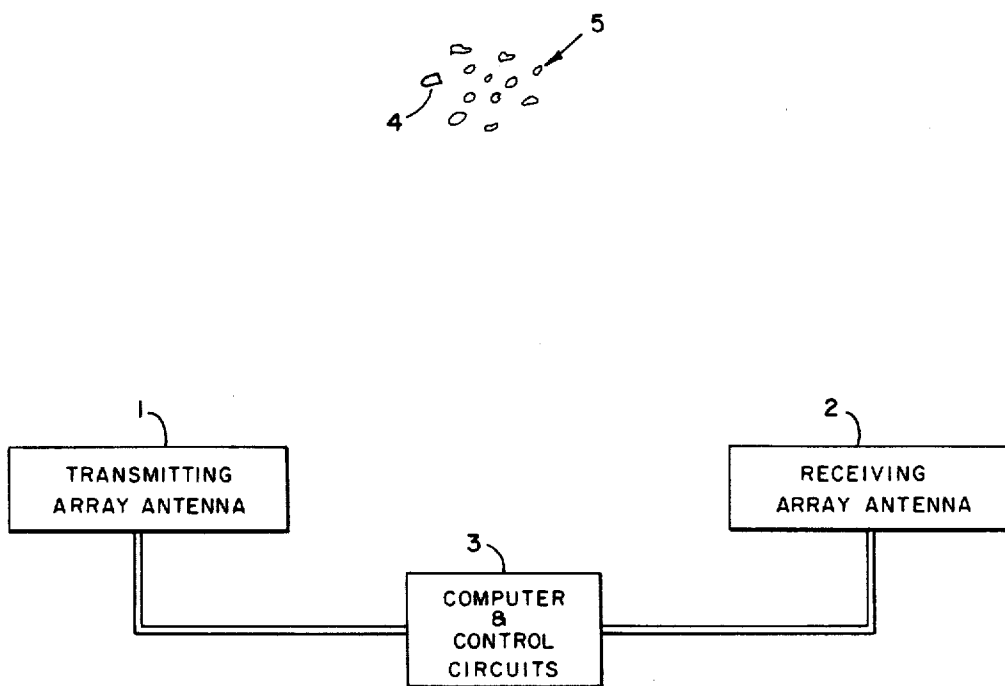


FIG. 1

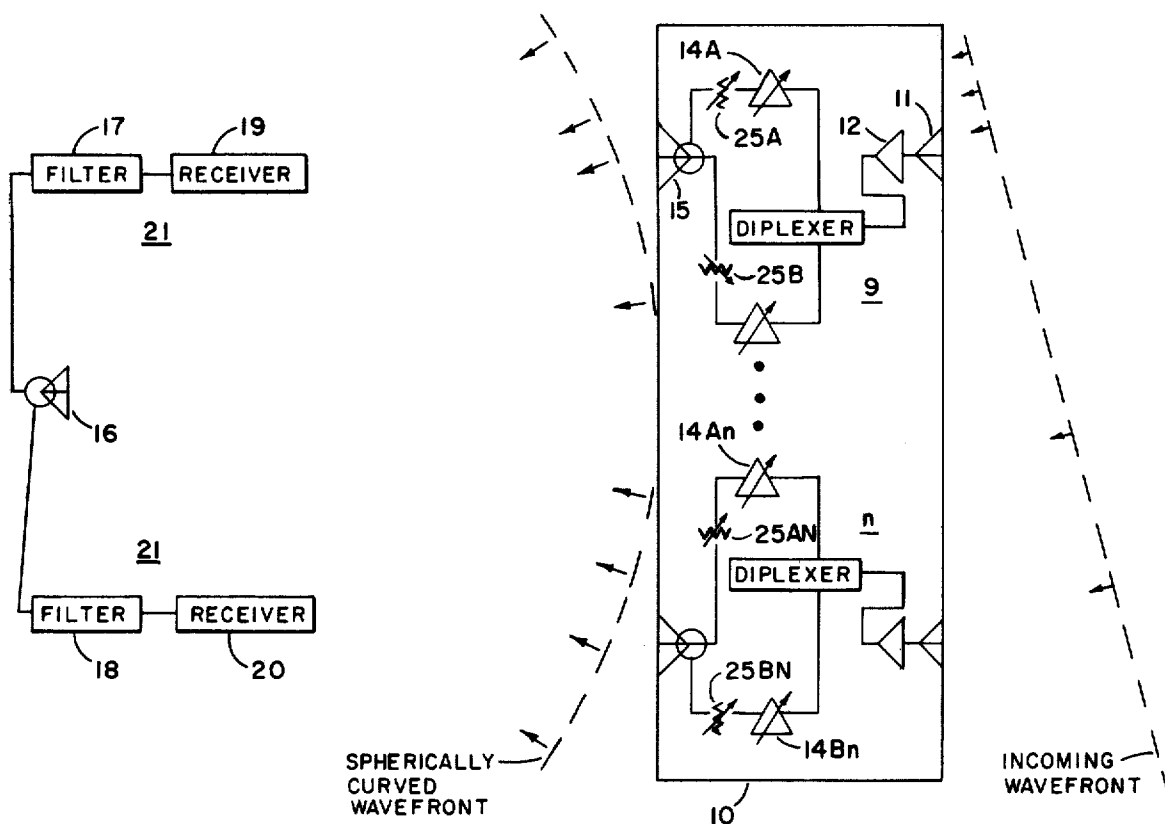


FIG. 2

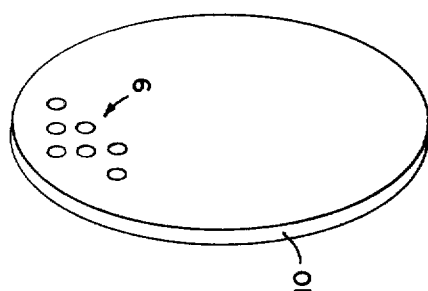


FIG. 5

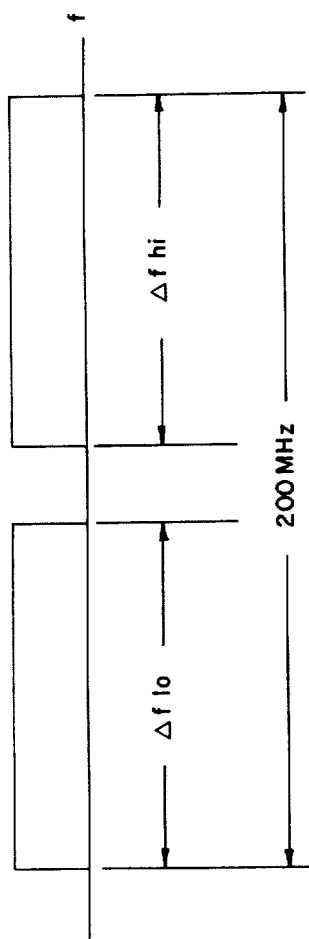


FIG. 3

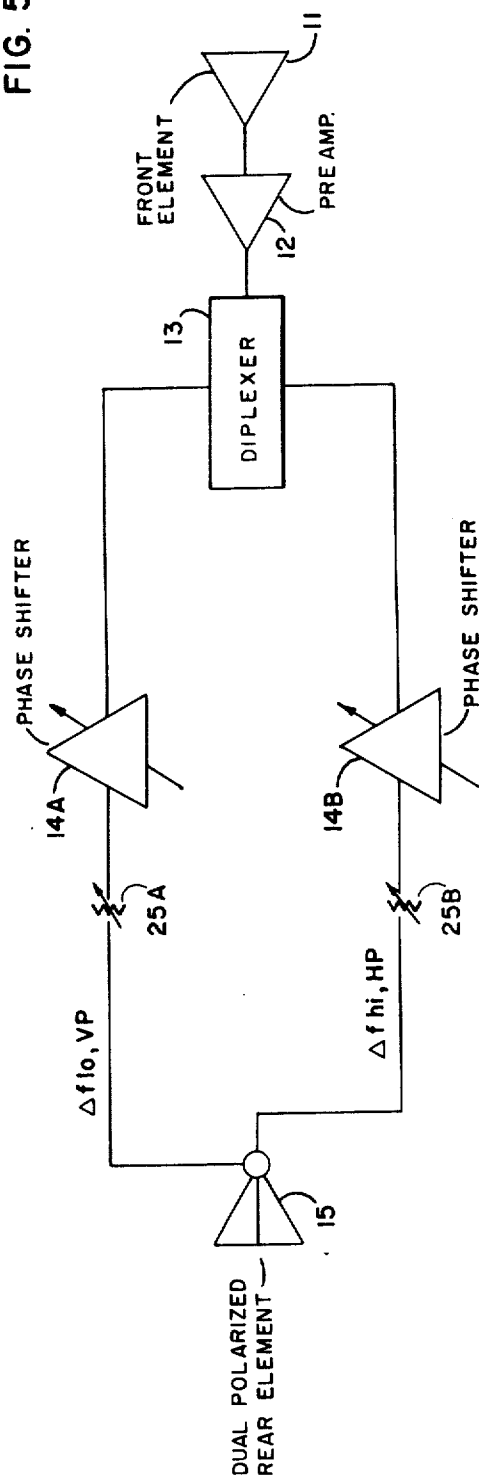


FIG. 4

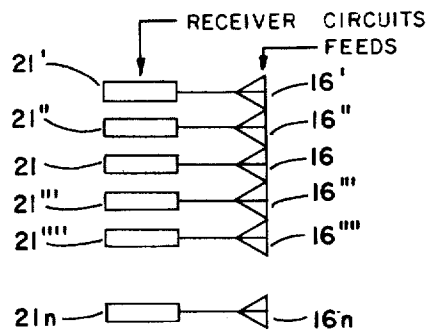


FIG. 6

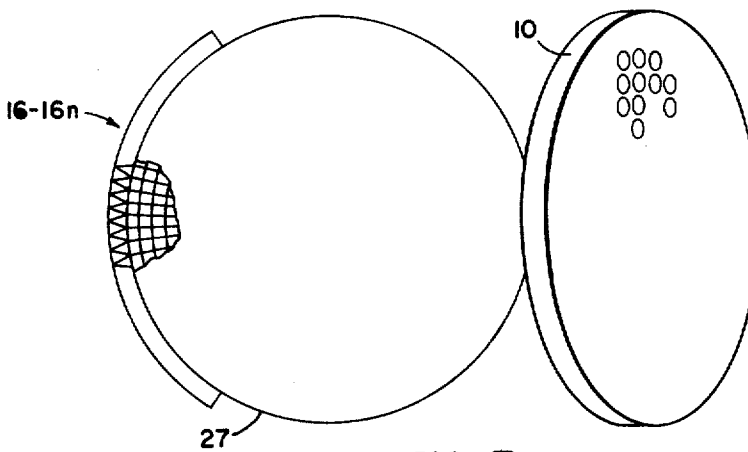


FIG. 7

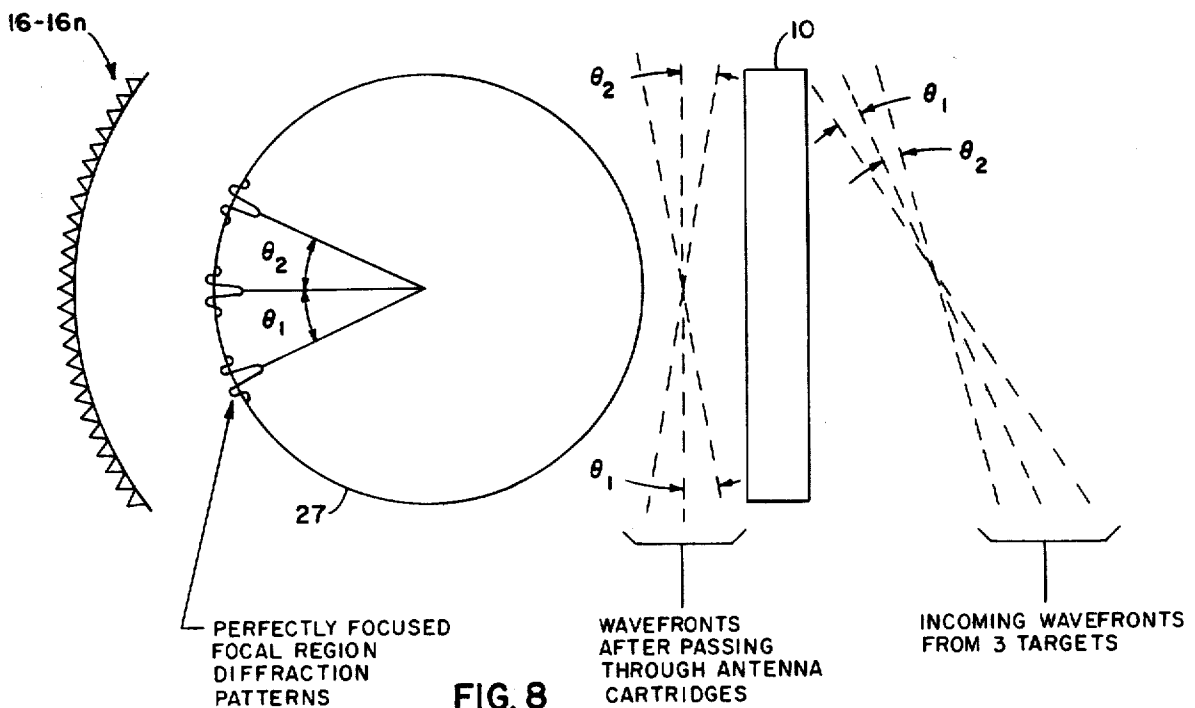


FIG. 8

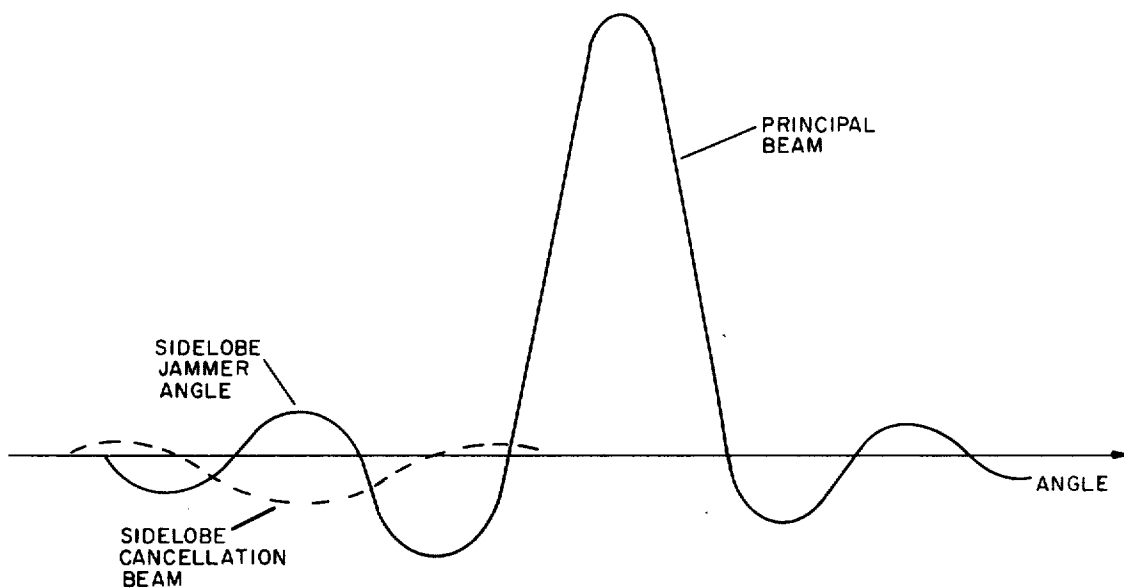


FIG. 9

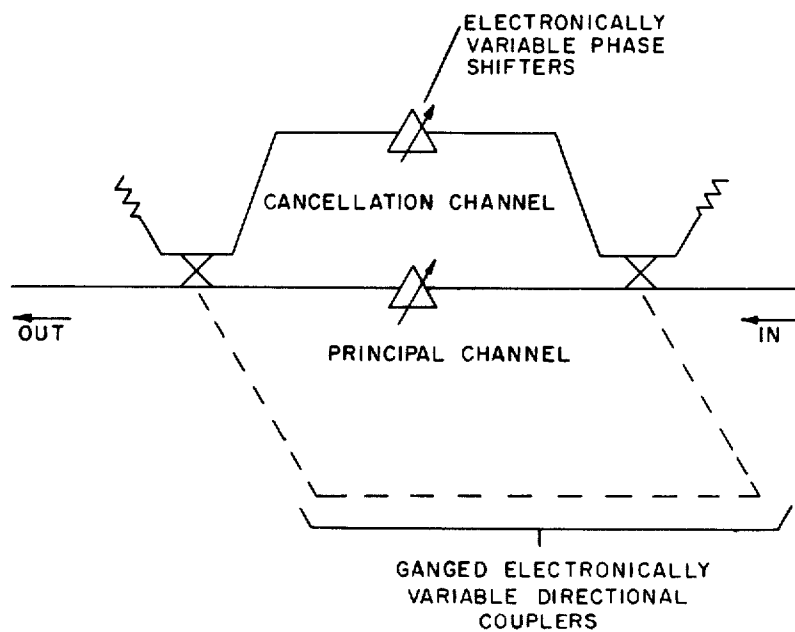


FIG. 10

SPACE FEED RECEIVER ARRAY

BACKGROUND OF THE INVENTION

This invention is related to the field of space feeding received radar returns from the antenna to the receiver circuits. Some related prior art are U.S. Pat. No. 3,406,399 and 3,496,569. The present invention improves over these patents in many ways; not least of which is the use of dual polarized feeding and receiving from elements.

SUMMARY OF THE INVENTION

A radar receiver antenna array containing a plurality of antenna cartridges is located spacial from the receiver feed horns. The antenna cartridges pick up radar returns and steer them through space to the feed horns which are connected to the receivers. Each antenna cartridge within the array consists of a front antenna element which intercepts the radar returns from targets, a preamplifier, and a diplexer which divides the total RF band into two sub-band channels. Each of the channels has an independently controlled electronic phase shifter which provides steering and focus control. Each channel is fed through a dual polarized rear feed which radiates the signals received from the two channels with different senses of polarization towards the focal region where the receivers are located. Further dual polarized rear feed horns are located in the focal region and each divides the signals back into two sub-band channels. Each channel contains a filter circuit connected between one of the receivers and the feed horn.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block showing of an overall radar system; FIG. 2 is a block diagram showing the space feed array of the present invention;

FIG. 3 is a showing of a frequency division of the dual channels;

FIG. 4 is a block diagram showing an individual dual channel cartridge of the present invention;

FIG. 5 is a diagrammatic showing of the array of antenna cartridges;

FIG. 6 is a block diagram shiwing an alternated receiver group from that shown in FIG. 2;

FIG. 7 is a diagrammatic showing of a lens correcting system;

FIG. 8 is an exploded view of the system shown in FIG. 7;

FIG. 9 is a showing of the superposition of antenna beams wave forms; and

FIG. 10 is a conceptual showing of an antenna cartridge.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 shows an overall view of the radar system. It consists of transmitting array antenna 1, receiving array antenna 2, and computer and control circuits 3. The transmitting array antenna 1 steers a signal pulse into space where it is reflected off any objects contained therein (for example warhead 4 and clutter 5). This signal is a broad band frequency signal in that it is to be divided into two frequency bands by the receiver. The reflected signals are received by the receiving array antenna 2 which is designed to individually process the two signal bands.

The space feed phased array receiver system is shown in FIG. 2. An array of antenna cartridges 9 is located in the antenna body 10 in the manner indicated by FIG. 5. A plane wave generated by the return from an object is shown to be obliquely incident upon the front face of the array. This incident wave is intercepted by the front antenna elements 11, etc. and is converted into a segmented (i.e., a guided) oblique wave front. The front elements are made up of dipole devices, horns or the like. The signal in each of the element modules is then preamplified and passed through electronically controlled phase shifters, which rectify the oblique wave front and also impart a spherical curvature to it in a manner well known in the art. After being phase shifted, the signals are radiated as a spherically converging wave front by elements located on the rear face of the array. At the center of the curvature of the spherical wave, a diffraction pattern is formed, and is intercepted by a feed horn 16 which is coupled to receivers 19 and 20. A plurality of other feed horns, filters and receivers may be supplied to provide coverage of a large number of objects in an area of search.

The configuration shown in FIG. 1 is capable of being steered to a single point in space at a given instant. The system provides the simultaneous formation and independent steering of tracking and search/discrimination beam clusters. Independent steering of two beams (or beam clusters) is also achieved.

The present system is capable of operating anywhere within an RF band of about 200MHz. Typically, there are a number of channels within this 200MHz which are used for frequency agile radar operation. However, during simultaneous track and search/discrimination operation, different RF channels are used for the different functions. In the proposed space feed radar organization two independently steered channels, operating on different RF channels, are attained as follows: The total 200MHz RF band is sub-divided into 2 sub-bands, as shown in FIG. 3. The individual element cartridges are modified to contain two channels, as shown schematically in FIG. 4. The element cartridge consists of an element pickup 11 on the front face of the array; a preamplifier 12; a diplexer filter 13 which places signals in the lower and upper RF sub-bands into different channels, each channel having its own independently controlled phase shifter 14A or 14B and electronically variable attenuator 25A or 25B. Phase shifters have outputs which feed into orthogonally polarized ports of a dual polarized rear element 15.

The entire dual channel array of FIG. 2 shows a receiving (collecting) dual frequency dual polarization feed horn 16. This feed horn is a dual polarized horn followed by filters 17 and 18 on the output ports. Each filter allows only one of the two RF bands to be coupled to its receiver 19 or 20. In operation, at any given instant of time, simultaneous steering of two beams is achieved by placing one beam on a channel in the upper sub-band, and the other beam on a channel in the lower sub-band. It is noted that the method of forming two channels shown in FIGS. 3 and 4 theoretically involves no loss of signal. Hence, the gain requirements of the preamplifiers 12 are not dictated by power splitting losses.

An examination of FIGS. 2 and 3 shows that the two beams are decoupled from one another by a combination of frequency and polarization discrimination. The use of polarization discrimination, in addition to frequency discrimination, permits the use of non-critical

filter designs. This arrangement reduces beam cluster to beam cluster cross-talk to a level below 40db. Packaging two channels within a single cartridge is done by high density strip line circuits. Also, modern integrated logic in the element cartridge is used to minimize the amount of hardware control circuits which are needed to control the multibit phase shifters in the two channels. Each of the individual elements 11-20 and 25 can take the form of any of the old and well known elements in the art.

The receiver group 16-20 may be a single group 21 as shown in FIG. 2. However, if a wide field of view is desired, a plurality of groups 21-21N may be provided with their feed horns arranged in the focal region as shown in FIG. 6. The focal region consists of a large number of feeds 16-16N. The feeds are dual port devices, with each port accepting a single sense of polarization and one of the two RF subbands.

The space feed array concept is in many respects similar to an optical system, and is therefore susceptible to the usual optical aberrations. Therefore, the simple focusing expedient of providing spherical curvature to a wavefront produces low aberration beams only for those beams corresponding to the feeds located near the centerline of the lens. To extend the field of view in the focal region, a corrective lens system can be placed between the rear face of the array and the feed cluster. A theoretically ideal correcting lens for a space feed array system is a Luneberg lens, as shown in FIG. 7. Single channel operation is readily explained with reference to the exploded view shown in FIG. 8. Returns from a three-target cluster are incident upon the array face 10. The three-target returns enter the array as plane waves and emerge as plane waves, with their angular orientation changed. In this case, the electronic phase shifters in the antenna cartridges accomplish only a prism, and not a focusing, function. The three plane waves are passed through the Luneberg lens and are perfectly focused to different points in the focal region, where their respective signals are intercepted by feed horns. While the Luneberg corrector lens 27 is both practical and feasible; however a less sophisticated correcting lens, designed by ray tracing techniques, can be incorporated in this space feed receiving array system. Included in this wide field of view design are features such as feed tilting of the extremal feeds to compensate the edge brightening of the corrector lens, and modification of the design of the feed horns corresponding to the extremal beams to compensate the reduction in the projected area of the rear face of the array.

In the operation of FIG. 2 the amount of phase shift imparted by shifters in the low sub-frequency group 14A-14AN is electronically controlled independent of shifters 14B-14BN. Therefore, the low subfrequency group could be tracking the warhead 4 (or a large reflecting object) while the high frequency sub-group could be tracking one object or group of objects in the clutter 5 for discrimination purposes. It can then be seen that the incoming wavefront returns on a given object could be in focus when processed by the low sub-frequency groups. However, when the returns from this same object are processed by the high sub-frequency groups, the returns are out of focus, as the high sub-frequency groups are being steered to look at a different portion of space.

The receivers 19 and 20 are connected to the computer 3 in order to send its information thereto. The

computers control circuits are connected to the phase shifters in order to provide independent steering in accordance to a desired program.

A scheme for eliminating sidelobe jamming is provided. The scheme consists of cascading the electronically controlled phase shifter 14 in each of the element channels with an electronically variable attenuator 25. These attenuators serve a dual function. The first use is to control aperture illumination of the antenna beam. In a phased array, both the phase and amplitude of each antenna element is adjusted to achieve a minimum of energy being lost in antenna beam side lobes. In general, the phase shifter adjusts the beam to aim in the desired direction and fixed attenuators are used to achieve the optimum illumination function. In a phased array which has variable beam width, it is desirable to have the ability to adjust under computer control the attenuation value for optimum performance depending on the beam width and aiming point, rather than have the fixed attenuation value which represents a compromise from optimum performance.

The second use of attenuators 25 is in side lobe cancellation. Referring to FIG. 9, the intention is to introduce a side lobe cancellation beam which is in antiphase to the side lobe response of the principal beam in the direction of the side lobe jammer. FIG. 10 shows how the side lobe cancellation could be accomplished conceptually. Operating at the same frequency, we generate two antenna patterns using a so-called principal channel and a cancellation channel. The phase shifters permit adjustment of the steering angle of the beams individually, with the principal beam aimed at the target and the cancellation beam aimed at the jammer. The relative amplitude of the cancellation beam with respect to the main beam is adjusted by varying the coupling between the two channels. This is only a conceptual scheme. In practice, it is more appropriate to recognize that FIG. 10 can be implemented by having in series a phase shifter and an attenuator and computing a combined setting which represents the correct value for the superimposed antenna patterns for each individual antenna element. As a matter of fact, conceptually, an infinite number of cancellation beams can be generated this way since when superimposed they all can be represented by a single phase shifter and attenuator setting for each individual antenna element. This cancellation feature, of course, can be built into either high frequency or low frequency channels or into both.

With this arrangement, it is possible to aim an antenna beam at a real target and simultaneously introduce an antenna pattern null at the sidelobe angle at which a jammer is located. Suppose a jammer is located at some sidelobe angle; at this angle it would be desirable to introduce an antenna pattern null without appreciably affecting the main beam. Conceptually, this can be effected by properly super-posing two antenna patterns. One channel is adjusted to steer the principal beam in the desired direction. The other channel steers a reduced amplitude beam to the angle at which jamming is occurring; with proper phase and amplitude settings in the channels, the main lobe of the reduced amplitude beam combines in antiphase with the sidelobe of the principal beam to create a null in the direction of the jammer.

The antenna cartridges in addition to aperture illumination control and side lobe cancellation perform dual separation of the separately steered signals. First the signals are separated in accordance to high and low fre-

5

quencies and then these signals are further separated by orthogonally polarizing the two signals. The receiver system can therefore separate the two signals both by polarization and by frequency. In the basic system shown in FIG. 1 the transmitting array antenna sends out a single wide band pulse to the targets. However, the transmitter could be broken down into two parts and transmit two pulses in the high and low frequency ranges towards different portions of space. The receiving array antenna 2 will separate the returns signals in the same manner in either case.

We claim:

1. An array antenna system comprising a plurality of cartridge means mounted in close spacial relationship to each other to form a unitary body; each cartridge means having an input and an output; a receiver unit having an input; each cartridge means detecting electromagnetic radiation entering its input and converting this radiation into an electrical signal which is split into two signals which are separately processed and are radiated out of the output of the cartridge means orthogonally polarized to each other; said receiver unit being located spacially from said plurality of cartridge means; the output radiations of said plurality of cartridge means being sent spacially to the input of said receiver unit; each cartridge means contains an elementary antenna located as the input of the cartridge means; a signal splitting means having an input and two outputs for splitting the signal at its input into two signals, one fed to one output and the other fed to the other output; said elementary antenna generating an electrical signal at its output in response to electrical magnetic energy received; the output of the elementary antenna being connected to the input of the signal splitting means; first and second phase shifters each having an input and an output; the output of the first signal splitting means being connected to the input of the first phase shifter; the other output of the phase splitting means being connected to the input of the second phase shifter; a dual polarized horn means having first and second inputs and first and second outputs; the output of the first phase shifter being connected to the horn means first input; the output of the second phase shifter being connected to the horn means second input; said horn means being the output of the cartridge means and generating the orthogonally polarized radiations; the output of each elementary antenna is a band of frequencies; and said signal splitting means being a diplexer means which divides the frequency band output of the elementary antenna into first and second frequency bands.

2. A system as set forth in claim 1 wherein said receiver unit comprises at least one further dual polarized horn means located spacially from the horn means of

6

each cartridge means; said further horn means each having first and second inputs and first and second outputs; the first input of said further horn means being aligned so as to pass any signal output from said first output of the plurality of horn means located in the cartridge means; said second input of said further horn means being aligned such that it will pass any signal outputs of the second outputs of the plurality of horn means in said cartridge means; first and second receiver means for each horn means; and means connecting the first and second outputs of each further horn means respectively to each first and second receiver means.

3. A system as set forth in claim 2 further comprising first and second filter means located respectively between the first and second outputs of said further horn means and said first and second receiver means; said first filter means passing frequencies of said first frequency band but not passing frequencies of said second frequency band; and said second filter means passing frequencies of said second frequency band but not passing frequencies of said first frequency band.

4. A system as set forth in claim 3 wherein each cartridge means further comprises a preamplifier connected between the output of the elementary antenna and the input of the diplexer means.

5. A system as set forth in claim 1 wherein said receiver unit comprises a plurality of dual polarized horn means located spacially from the horn means of said cartridge means; and lens correcting device located between the horn means of said cartridge and the plurality of the horn means of the receiver unit so as to compensate for optical aberrations.

6. A system as set forth in claim 5 wherein each receiver unit comprises a dual polarized horn means located spacially from the horn means of the cartridge means; said horn means each having first and second inputs and first and second outputs; the first input of each horn means being aligned so as to pass any signal output from the first output of the plurality of horn means located in the cartridge means; said second input of each horn means being aligned such that it will pass any signal outputs of the second outputs of said plurality of horn means in the cartridge means; first and second receiver means for each horn means; said first and second outputs of each receiver horn means being connected respectively to each first and second receiver means; and further comprising first and second variable attenuators connected respectively between the outputs of said first and second phase shifters and the first and second inputs of said dual polarized horn means located in the cartridge means.

* * * * *

55

60

65