Goddard

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

(NASA-Case-GSC-11013-1) PLURAL BEAM ANTENNA Patent (NASA) 7 p CSCL 09E N73-19234

Unclas
00/09 64779

REPLY TO ATTN OF: GP

TO: KSI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,713,163

Government or Corporate Employee : U.S. Government

Supplementary Corporate Source (if applicable) : ______

NASA Patent Case No. : GSC-11,013-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:
Yes ☐ No ☑

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words ". . . with respect to an invention of . . ."

Elizabeth A. Carter

Elizabeth A. Carter
Enclosure
Copy of Patent cited above

United States Patent [19]

Keller et al.

[11] **3,713,163**

[45] **Jan. 23, 1973**

[54] **PLURAL BEAM ANTENNA**

[75] Inventors: **George C. Keller**, Hyattsville, Md. 20783; **Marvin S. Maxwell**, Silver Spring, Md. 20902; **Louis R. Dod**, Silver Spring, Md. 20901

[73] Assignee: **The United States of America as represented by the Administrator of the National Aeronautics and Space Administration**

[22] Filed: **Nov. 22, 1971**

[21] Appl. No.: **200,717**

[52] **U.S. Cl.** **343/754,** 343/839, 343/854, 343/895

[51] **Int. Cl.** **H01q 3/26**

[58] **Field of Search**.......343/754, 761, 839, 854, 895

[56] **References Cited**

UNITED STATES PATENTS

3,534,365 10/1970 Koruin et al...................................343/854

Primary Examiner—Eli Lieberman
Attorney—R. F. Kempf et al.

[57] **ABSTRACT**

An antenna capable of deriving a plurality of beams about a single boresight axis includes a focusing means, such as a parabolic reflector or a lens. Plural arrays, each including plural radially aligned antenna elements extending from the boresight axis, are located in proximity to a focal point for the focusing means. The elements of the plural arrays are independently excited. Each of the arrays is independently rotated about the boresight axis.

8 Claims, 5 Drawing Figures

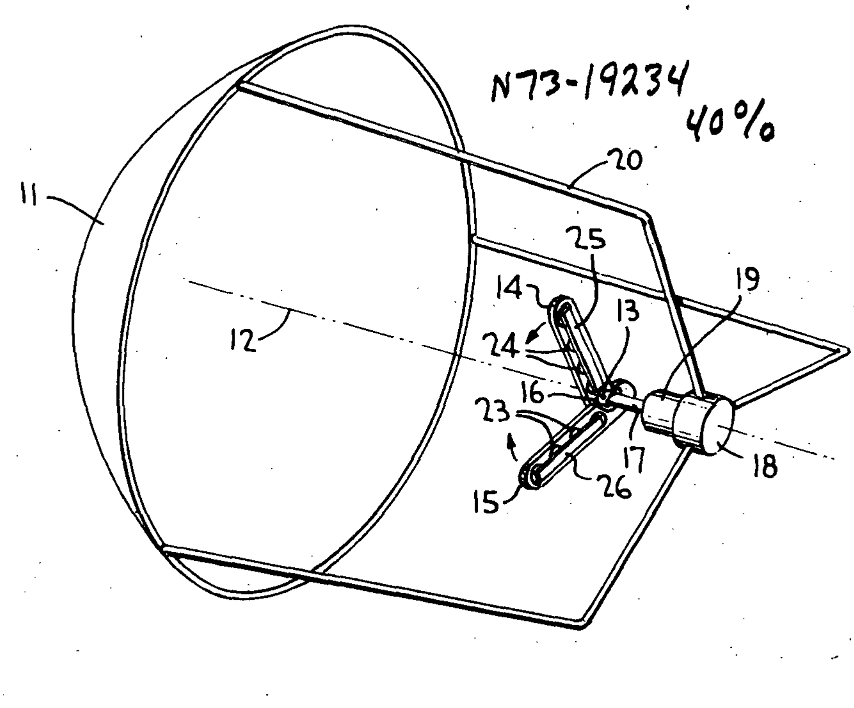


FIG. 1

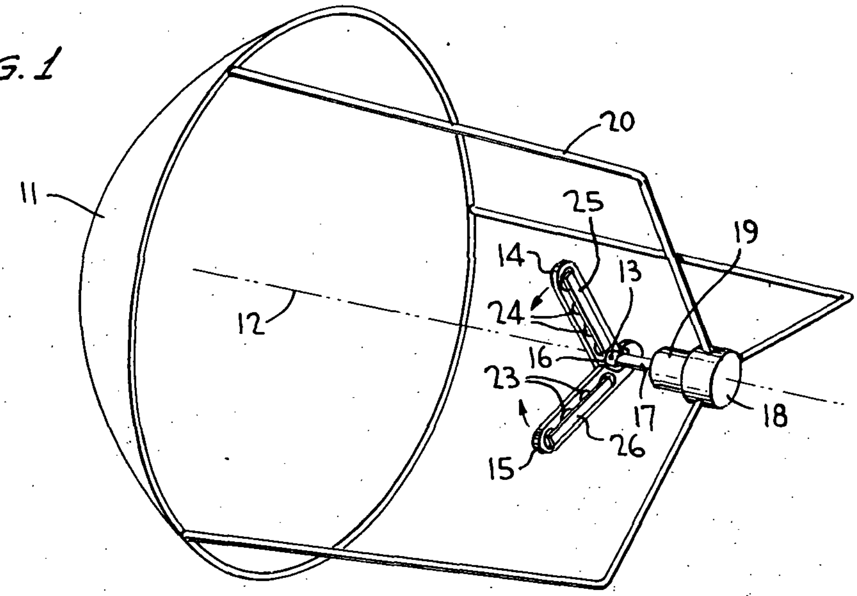


FIG. 2

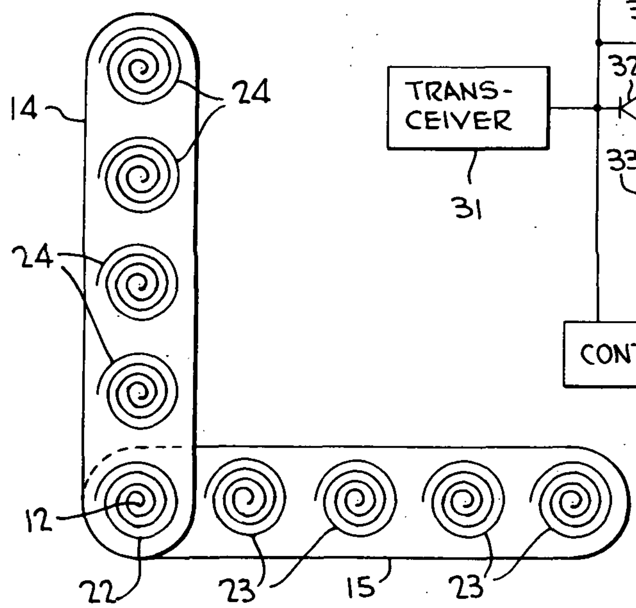
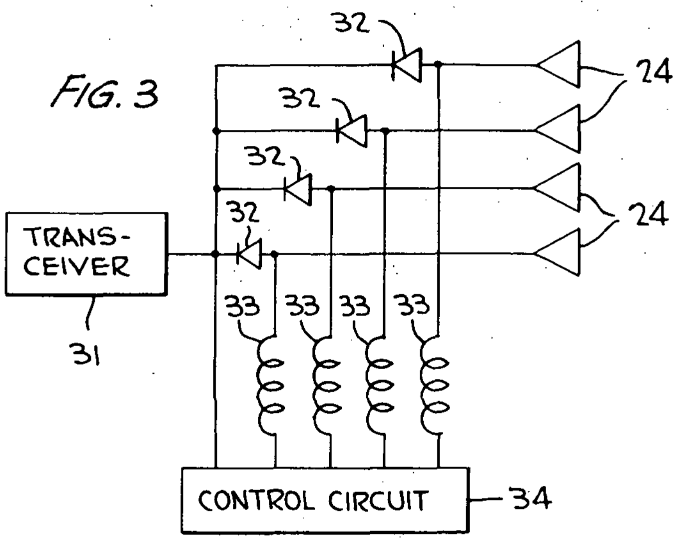


FIG. 3



INVENTORS

GEORGE C. KELLER
MARVIN S. MAXWELL
LOUIS R. DOD

BY Earl Levy

ATTORNEYS

FIG. 4

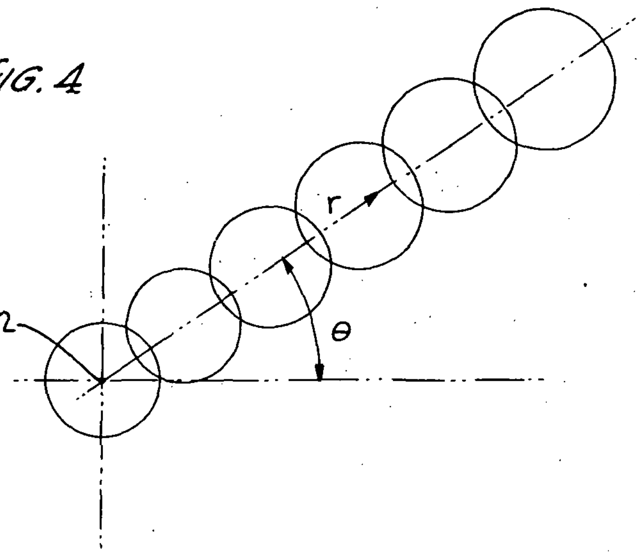
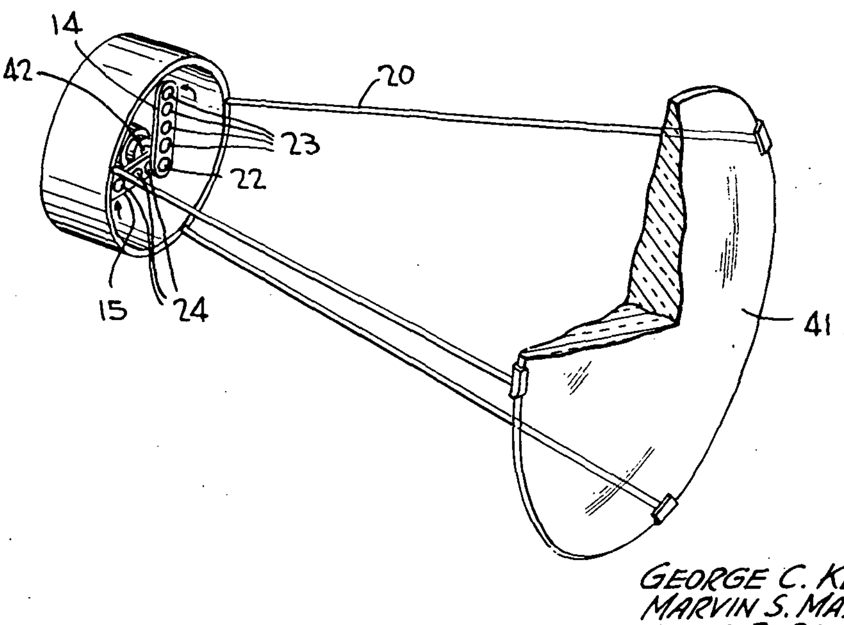


FIG. 5



INVENTORS,
GEORGE C. KELLER
MARVIN S. MAXWELL
LOUIS R. DODD

BY Earl Levy ATTORNEYS

PLURAL BEAM ANTENNA

ORIGIN OF THE INVENTION

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

FIELD OF INVENTION

The present invention relates generally to antennas and more particularly to an antenna including a plurality of independently rotatable arrays, each including plural radially aligned antenna elements extending from a boresight axis.

BACKGROUND OF THE INVENTION

In many tracking and communications applications with moving targets, it is desirable simultaneously to form plural independent, steerable beams with an antenna having a single aperture. Generally in the past, plural antenna apertures, formed by plural movable parabolic reflectors or the like, have been used for simultaneously tracking and communicating with plural moving targets, with one aperture being assigned to each target. Tracking and communicating with plural targets has also been performed by utilizing multibeam phased arrays, including many antenna elements, or focusing structures including phased array feeds. It has also been proposed to employ a rotating linear feed in combination with an articulating parabolic reflector to achieve simultaneous tracking and communications with moving targets.

Each of the proposed prior art structures suffers from certain disadvantages. The plural reflector approach, in addition to being costly, requires precise movement and control of relatively large masses. If these massive reflectors are mounted on a spacecraft, problems in controlling the spacecraft position result in response to movement of the reflectors. The multibeam phased arrays, in actuality, are low efficiency devices because each of the many switches and/or hybrids employed has a finite loss which becomes substantial when many of them are interconnected in a cascade relationship to form a complete array. Also, control circuits for the phased arrays are frequently in the form of a complex electronic network. The rotating linear feed suffers from some of the same problems as the plural reflector systems because of the requirement to position accurately the relatively massive articulated reflectors utilized with the feed. In addition, the reflector must frequently be articulated to a different position to track more than one target, whereby simultaneous derivation of plural different beams, for a plurality of different targets, is often not possible.

SUMMARY OF THE PRESENT INVENTION

In accordance with the present invention, there is provided a single fixed aperture antenna capable of simultaneously deriving plural beams for tracking and communicating with plural targets. The antenna is provided with a plurality of antenna arrays, each including plural antenna elements on a straight or curved arm one end of which is mounted to pivot about the boresight axis, and a focusing structure, such as a parabolic reflector or a lens, for focusing the beams of the antenna arrays. Each of the arrays, which are positioned in proximity to the focal point, is independently rotatable and the elements of the several arrays are independent activated by a simple switching network, whereby one or more of the elements of each array is excited at a time. The antenna elements in each array are spaced closely enough together so that the beams derived by adjacent antenna elements overlap substantially so that significant nulls do not occur in the overall antenna pattern. As the plural arrays are rotated about the boresight axis and the several elements of each array are activated, complete coverage of the antenna aperture field of view is provided for several targets, at least equal to the number of arrays provided. Thereby, simultaneous tracking and communication with each target is possible.

It is, accordingly, an object of the present invention to provide a new and improved antenna capable of simultaneously tracking and communicating with plural targets.

Another object of the present invention is to provide an antenna having a fixed, single aperture capable of simultaneously tracking and/or communicating with plural moving targets.

A further object of the invention is to provide a new and improved antenna system capable of simultaneously tracking and/or communicating with plural moving targets, which antenna system employs a relatively simple and high efficiency network for selectively exciting a plurality of antenna elements.

Still another object of the present invention is to provide a new and improved antenna system particularly adapted for use on spacecraft and capable of tracking and/or communicating with plural targets without having an effect on position control of the spacecraft.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of several specific embodiments thereof, especially when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 is a perspective view of one preferred embodiment of the present invention;

FIG. 2 is a pair of arms, as viewed from the vertex of the reflector, included in the antenna of FIG. 1;

FIG. 3 is a diagram of the circuit utilized to excite the elements of one of the arrays of the antenna system illustrated by FIG. 1;

FIG. 4 is a view illustrating the overlap in antenna patterns from an array of the antenna system of FIGS. 1 and 2; and

FIG. 5 is a modification of the system of FIGS. 1 and 2, illustrating the use of a lens for focusing the beams.

DETAILED DESCRIPTION OF THE FIGURES

Reference is now made to FIGS. 1 and 2 of the drawing wherein there is illustrated a beam focusing structure comprising parabolic reflector 11 having a boresight axis 12 on which lies reflector focal point 13. Positioned in proximity to and on either side of focal point 13 are curved or straight arms 14 and 15 which extend radially from boresight axis 12. Arms 14 and 15 are independently driven by concentric shafts 16 and 17, which are coaxial with boresight axis 12. Shafts 16 and 17 are driven independently by a pair of motors 18 and 19 which rotate the shafts and arms 14 and 15 either at the same or different predetermined rotational velocities or in response to tracking command signals. The entire assembly including arms 14 and 15, shafts 16 and 17 and motors 18 and 19, is supported by any suitable means, such as struts 20 which are fixedly mounted to the edges of reflector 11.

Each of arms 14 and 15 carries a plurality of antenna elements positioned with respect to reflector 11 to enable a number of relatively narrow width secondary beams (FIG. 4) to be derived by the reflector in response to excitation of the elements. The plural elements mounted on each of arms 14 and 15 extend away from the boresight axis 12 and are positioned a different radial distance from the boresight axis. Arms 14 and 15 can be planar or curved. If the arms are curved, the curvature is selected to give the best fit for the focusing plane, as described in Korvin et al. U.S. Pat. No. 3,569,976. Arm 14, the closer of the two arms to reflector 11, can be provided with an antenna element 22 centered on the boresight axis 12. Excitation of antenna element 22 centered on boresight axis 12 results in a far field pattern of reflector 11 coincident with the boresight axis. Arms 14 and 15 are provided with an equal plurality of off axis antenna elements 23 and 24 to enable beams having centers displaced from boresight axis 12 to be derived. The centers of the off axis beams are determined by the angular positions of arms 13 and 15 relative to boresight axis 12, as well as the radial positions of the off axis excited elements. Adjacent ones of elements 23 and 24 of each of arms 14 and 15 are positioned in close enough proximity to each other whereby the 3 db beam widths resulting from excitation of the different elements have a substantial overlap, as indicated by the far field patterns of FIG. 4. Thereby, complete coverage of the desired field of view of the aperture of parabolic reflector 11 is attained by rotation of the arms and excitation of the elements. Simultaneous tracking and communication with two targets is achieved through rotation of both of arms 14 and 15 independently by motors 18 and 19. If a pair of targets simultaneously approaches the boresight axis and comes within the field of view of the beam formed by the antenna element in alignment with boresight axis 12, a communication and/or tracking link is established only with centrally located antenna element 22 on arm 14 by deactivating elements 23 and 24. Similarly, when the arms, in their rotation, cross over each other, the communication and/or tracking link is established only with arm 14 until the arms separate sufficiently for each to resume communication and/or tracking separate targets. If simultaneous tracking and/or communication with more than two targets is desired, the number of arms is increased accordingly so that one arm is provided for each target.

The antenna elements 22, 23 and 24 on arms 14 and 15 are preferably cavity backed spirals of the type well known to those skilled in the art. The spirals can be employed with cavities having air dielectrics, but are preferably employed with cavities having solid dielectrics with dielectric constants greater than one, whereby the depth of the cavity can be decreased so that the emitting surfaces of the spirals can be placed in greater proximity to the focal surface which includes focal point 13 and is normal to boresight axis 12 to effect maximum gain of the antenna so that the responses for excited elements on arms 14 and 15 having the same radial displacement from boresight axis 12 are approximately equal. The emitting surfaces of the spirals are approximately equidistant from this plane. Cavity backed spirals are preferably employed because of the circularly polarized beams derived thereby. The spirals can be of the two-armed type if communication only is desired; four-armed spirals are employed, as disclosed in U.S. Pat. No. 3,344,425, when the antenna system is utilized for tracking. While spirals are utilized as the antenna elements in FIG. 2, it is to be understood that other antenna elements, such as crossed dipoles, linear dipoles, horns and optical systems, may be utilized depending on the function desired and frequency employed.

Positioned on the rear faces of arms 14 and 15, that is, the faces of the arms away from reflector 11, are switching networks and active devices, such as transmitters, receivers or transceivers. The switching and active elements may be located on arms 14 and 15 in flat boxes 25 and 26, respectively, and thereby rotate with the arms to obviate the need for crossing a rotating interface, such as a slip ring, at low signal levels. Box 25 is as flat as possible so that it does not contact the front face of arm 15 or displace the radiating elements too far from the plane including focal point 13.

A typical circuit for exciting elements 24 on arm 15 is illustrated in FIG. 3 wherein an active device 31, such as a transceiver, is selectively connected to one or more of elements 24 at a time. Connected in series between transceiver 31 and each of antenna elements 24 is a separate PIN diode 32 which is normally back biased to a nonconducting state in response to D.C. blocking voltage applied thereto through RF choke 33 by control circuit 34. To excite an antenna element 24, the diode 32 connected in series with the element to be excited is activated to a forward biased condition in response to a positive voltage being applied to its anode by a positive voltage being derived at an output terminal of control circuit 34. When it is desired to scan an area, the several output terminals of control circuit 34 are supplied in sequence with positive voltages so that at any time a positive voltage is applied to only one of the diodes 32. Switching diodes 32 to a forward biased condition is at a much faster rate than rotation of arm 15. Simultaneously, arm 14 is being rotated and the several active elements mounted thereon excited in response to the diode switches in box 25 being forward biased. The active devices 31 in boxes 25 and 26 operate in the same band, for example S band (between 2.2 and 2.3 GHz). The frequency of each active device is, however, different to enable tracking and communication with targets having different frequency characteristics.

For tracking applications, control circuit 34 responds to signals derived from the excited antenna element 24, or predetermined commands, to forward bias the diode 32 connected to the active element having a radial position corresponding with the off axis position of the tracked target. Also, the angular position of arm 15 about boresight axis 12 is controlled in response to signals derived from the active antenna element **24** feeding error signals from the element or from predetermined command signals to the motor **19**. In response to the signals derived from the excited antenna element **24** exceeding a predetermined level, or from a command, motor **19** is rotated or excitation of the antenna elements **24** is switched to an adjacent element.

Reference is now made to FIG. **5** of the drawing wherein there is illustrated a modification of the system illustrated by FIG. **1**. In FIG. **5**, the beam focusing structure, illustrated in FIG. **1** as parabolic reflector **11**, comprises focusing lens **41**, having its major axis approximately perpendicular to the faces of arms **14** and **15**. The focal point **43** of the lens **41** lies on the pivots of arms **14** and **15**. The system of FIG. **5** functions in a similar manner as the antenna system of FIG. **1** to derive simultaneously a plurality of beams having independently controlled positions about boresight axis **12** as a function of radius and angular position.

While there have been described and illustrated several specific embodiments of the invention, it will be clear that variations in the details of the embodiments specifically illustrated and described may be made without departing from the true spirit and scope of the invention as defined in the appended claims.

We claim:

1. An antenna capable of deriving a plurality of energy beams centered about a single boresight axis having a focal point for the beams comprising plural arrays of plural antenna elements in proximity to the focal point, means for focusing the beams on the antenna elements, said elements of each array being aligned and spaced by a different distance from the boresight axis, means for independently exciting elements of the plural arrays, and means for independently rotating each of the plural arrays about the boresight axis.

2. The antenna of claim 1 wherein the elements are positioned so that radiation beams derived from adjacent elements overlap.

3. The antenna of claim 1 wherein a pair of said arrays is provided, one of said arrays being positioned on one side of the focal point, the other of said arrays being positioned on the other side of the focal point.

4. The antenna of claim 1 wherein the focusing means includes a reflector.

5. The antenna of claim 1 wherein the focusing means includes a lens.

6. The antenna of claim 1 wherein one of the arrays is displaced from the other arrays along the boresight axis, said one array being positioned between the focusing means and said other arrays, said one array including an element having its center on the boresight axis.

7. The antenna of claim 1 wherein the means for exciting includes switch means selectively connecting each of the elements in circuit with an active device.

8. The antenna of claim 1 wherein different arrays are located on either side of the focal point.

* * * * *