343-754 CROSS REFERENCE

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LUNEBERG ANTENNA SYSTEM FOR SPIN STABILIZED VEHICLES

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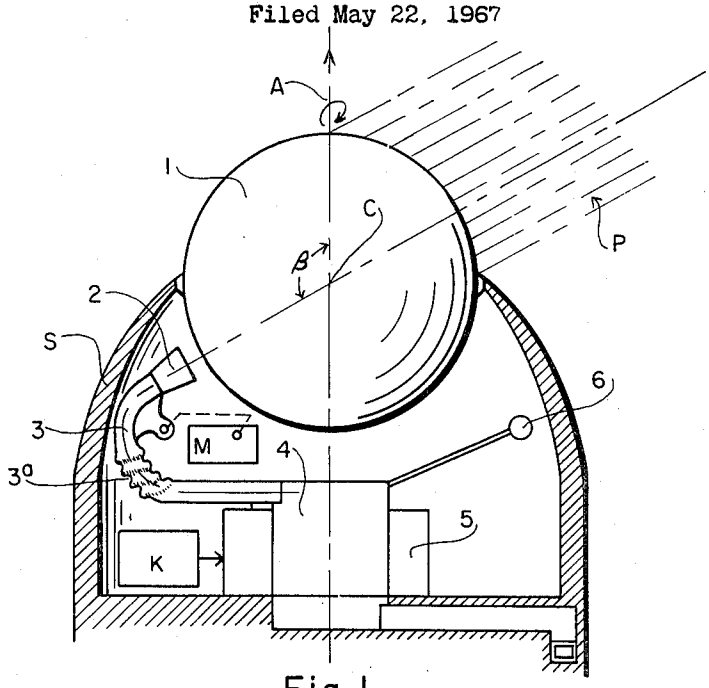


Fig. 1

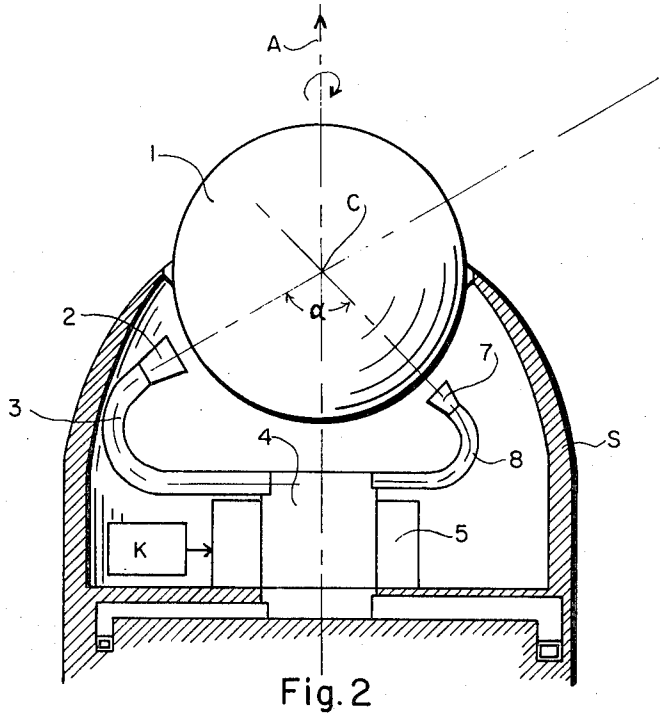


Fig. 2

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LUNEBERG ANTENNA SYSTEM FOR SPIN STABILIZED VEHICLES

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ABSTRACT OF THE DISCLOSURE

An antenna system for vehicles which rotate about a spin axis, the antenna system illustrated herein including a spherical lens of a type which transforms between collimated microwaves moving in a substantially plane front on one side of the lens, and a focused point on the opposite side of the lens, the lens being mounted to an end of the vehicle concentric with its spin axis and blending into the vehicle's exterior skin shape, and the only moving parts being associated with one or more small waveguide horns located inside the vehicle and rotated contrary to the direction of vehicle spin to maintain the horn, or horns, always diametrically opposite relative to the center of the lens from the body outside the vehicle with which communication is being conducted.

This invention relates to improved antenna systems having special utility for mounting in satellites, for example synchronous communication satellites, or in rockets or spacecrafts, or other vehicles which are spin-stabilized, such stabilization being especially attractive because of reliability, and cost considerations.

In connection with communication antennas for mounting on spin stabilized spacecrafts, it is difficult to accomplish high antenna gains because this requires a narrow-beam antenna pattern, a pencil beam, which can always be accurately directed. Therefore such a pattern must be at the satellite's spin frequency but in the opposite direction. The antenna can be counter-rotated either electronically or mechanically. In a prior-art system in which its beam is counter-rotated electronically, there are many antenna circuit elements, for example a dipole array symmetrically assembled about the spin axis and controlled by phase shifters. The disadvantages of this electronic device are: heavy weight, substantial power consumption of the phase shifters, poor reliability because of the circuit complexities involved, and unsatisfactory antenna hardware.

The other alternative, mechanical rotation, requires the rotation of a directional antenna, for example a parabolic dish. The disadvantages of this approach are: the heavy load of the moving masses, friction problems as a result of the motion, and unwanted gyroscopic reaction of the heavy antenna which disturbs the attitude of the spacecraft.

This invention provides a novel and improved antenna system for communication from-and-to spin stabilized rockets, satellites and space probes, employing a lens mounted along the spin axis of the vehicle and blending smoothly into its exterior shape, with minimal moving parts which are located behind the lens inside the vehicle. It employs a lens which is symmetrical about its center and the spin axis of the vehicle, for example a spherical "Luneberg lens" as described in U.S. Pat. No. 2,849,713, which is composed of a number of concentric layers of a stable expanded dielectric plastic substance wherein the index-of-refraction is properly chosen so that the lens transforms between a collimated wave moving in a plane front on one side of the lens, and a focused point on the other side. This type of mounting places the focused point inside the spacecraft, but leaves a much larger effective lens aperture equal virtually to the diameter of the spherical lens outside the craft.

The focused point always remains diametrically opposite to the remote location being communicated with, relative to the center of the lens, and therefore as the vehicle rotates, this point moves about the interior surface of the lens in an annular path. The present system therefore includes feed antenna means, i.e., microwave horn means, which follow the motion of the point by performing synchronized rotation about said annular path in a direction contrary to the rotational direction of vehicle spin. The focused point is thus maintained opposite the aperture of the small internal feed antenna, whether the system is transmitting or receiving, the small feed antenna being connected to suitable T/R coupling means. The optimum radio frequency used for such communication is preferably within the range of 1 to 10 gigahertz, which frequencies lend themselves well to being "beamed" directly toward and locked onto a remote transmit/receive facility, for instance a stationary receiver and transmitted on the surface of the earth.

Further objects and advantages of the invention will become apparent during the following discussion of the illustrative embodiments shown in the drawing, wherein:

FIG. 1 is a view taken through the spin axis of a vehicle and showing the vehicle's skin in cross-section, but showing the Luneberg lens and antenna components in elevation; and

FIG. 2 is a view similar to FIG. 1, but showing a system including two feed antennas rotatably mounted behind the lens.

Referring now to the drawing, both figures show in cross-section a portion of a spin-stabilized vehicle body including skin S, the body rotating about a spin axis A, and said rotation being under the supervision of space vehicle control and motor means (not shown) which continuously maintain the vehicle spin axis A at a predetermined attitude, for example with respect to the earth or to some other coordinate system. The upper end of the skin S is preferably shaped to receive and mount a Luneberg lens 1, the present mounting showing the lens supported at a great circle of the sphere, although more or less of the lens can be exposed outside the vehicle as may appear desirable. The lens need not be spherical, but may be shaped as desired in order to optimize the practical design.

A horn feed 2 is directed always toward the center C of the lens 1, and this horn is coupled to a waveguide 3 and then through a rotating joint 4, which is concentric with said spin axis A, to a transmit/receive switch (not shown) within the spacecraft. The horn feed is constructed to generate almost a point-pattern directed at a fixed angle β to said rotation axis A, for example $\beta=120°$. This point is then translated by the Luneberg lens into a collimated plane-front beam pattern P. The horn feed is rotated in this angular position about an annular path by suitable drive bearing means 5 which are controlled by instrumentation K so that the horn 2 is always precisely on the opposite side of the center of the Luneberg lens with respect to the radio station on earth, i.e., it is synchronously counter-rotated to cancel out the spinning motion of the spacecraft about axis A. The weight 6 counterbalances the mass of the horn 2 and waveguide 3. During the initial establishment of contact with the earth station, it may be desirable to include in the instrumentation K means for selectively rotating the antenna horn 2 faster or slower than the spin rate of the spacecraft for search purposes.

The direction of the beam P can be changed by providing a joint or a flexible bellows section 3*a* in the wave-

guide 3 so that the horn 2 can be directed through the center C of the lens 1 from a different angle relative to the axis of symmetry of the lens, the mechanical actuator comprising, for example, a motor M.

One of the major advantages of the present inventive system is that only a light weight horn feed is rotated, and therefore the problems which are concerned with drive bearings and with the friction of moving parts under space conditions, and with gyroscopic reactions affecting the attitude of the spacecraft are accordingly minimized.

FIG. 2 shows a further illustrative embodiment based upon the fact that the symmetry of the lens with respect to its center makes it possible to use more than one feed antenna simultaneously, for instance communicating in other desired directions. Parts in FIG. 2 which are the same as those shown in FIG. 1 are labeled with the same reference characters.

There are many possible combinations of these parts, and several useful possible counter-rotation velocities. The horn drive can cause the several horns to "stand still" so that they point in constant directions with respect to external coordinate frames of reference, or the counter-rotation rate can be a multiple or a submultiple of the vehicle-spin rate, and the horns can operate alternately. For instance, the horn feed 2 can be used as a receiving antenna, and another horn feed 7 which is arranged at a fixed angle α with respect to the horn feed 2 can be fed for transmission via the waveguide 8. The latter transmitting feed and antenna should be designed for a higher frequency than the receiving antenna. The two rotating antennas need not, as shown, be in the same plane. With this latter arrangement it is possible to build up a microwave relay system between two fixed places on earth, preferably via synchronous satellites.

It is possible by further mechanical or electronic means to shift the angle β in FIG. 1 in a desired manner while the system is in operation and perhaps simultaneously with a controlled variance of the counter-rotating frequency of the horn feed, thereby to track the beam of the antenna system with the motion of a remote station or vehicle with which communication is being conducted.

The present invention is not to be limited to the illustrative embodiments shown and described, for obviously changes may be made therein within the scope of the following claims.

What I claim is:

1. An antenna system for radio wave communication aboard a spinning vehicle having a body with an opening therein disposed on the vehicle spin axis, comprising:
   (a) a Luneberg dielectric lens fixed in the opening of the body, the lens being symmetrically disposed about the spin axis and mounted in said opening in that body with portions of the lens facing respectively inside and outside of the body;
   (b) feed antenna means inside of the body and operatively directed toward the lens; and
   (c) means to counter-rotate the feed antenna means around the vehicle spin axis at a rate which is synchronized to bear a predetermined relationship to the rotation rate of the vehicle.

2. A system as set forth in claim 1, in which the lens has an axis of symmetry which coincides with the spin axis of the vehicle.

3. A system as set forth in claim 1, wherein said antenna feed means includes plural antenna horns directed toward the lens from different angles with respect to said axis of symmetry.

4. A system as set forth in claim 1, including means for changing the angle of the feed antenna with respect to the axis of symmetry of the lens.

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