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PASSIVE REPEATER FOR SATELLITE COMMUNICATION SYSTEMS

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FIG. 1

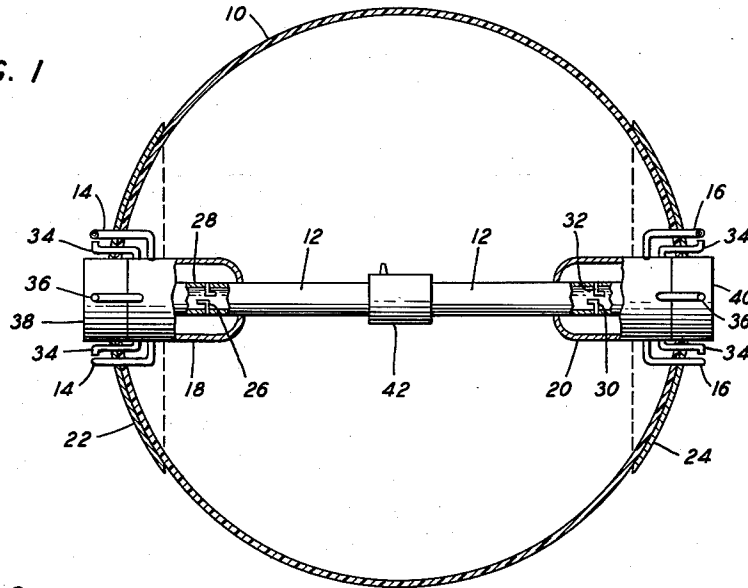


FIG. 2

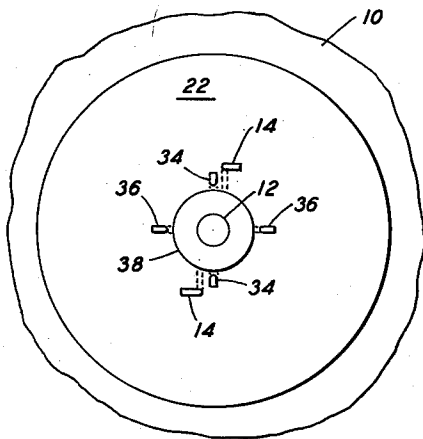
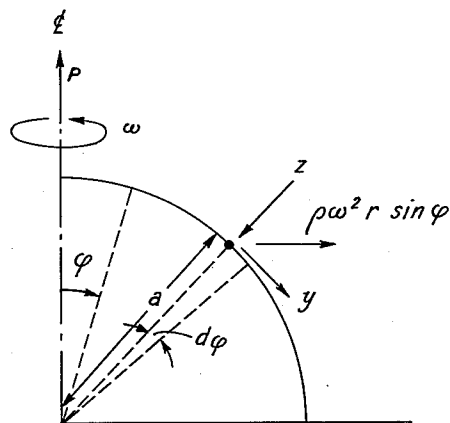


FIG. 3



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PASSIVE REPEATER FOR SATELLITE COMMUNICATION SYSTEMS

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8 Claims. (Cl. 244-14)

This invention relates to space satellites and, more particularly, to satellites adapted for use as passive repeaters in radio communication systems.

With the successful launching into relatively stable orbits of space satellites of the earth, many proposals have been made for the use of satellites as the repeater stations of radio relay systems arranged for beyond-the-horizon communication. The simplest satellite vehicles proposed for this purpose consist of nothing more than a large spherical balloon having a metallized envelope and presumably capable of being carried into orbit in a collapsed condition and there inflated to serve as a reflector for radio waves. Such a repeater structure is attractive because of its low mass and the small space required in the vehicle by which it is transported into orbit.

Various proposals have been advanced for the solution of the problem of inflating or erecting the spherical envelope after the satellite has been transported into orbit. The most obvious of these involves the use of a gas charge or a charge of water vapor or the like which is released within the folded envelope when the latter is launched into orbit and presumably exerts sufficient internal pressure to remove the folds and creases from the envelope and to cause the envelope to assume the desired spherical shape. Calculation has indicated that a substantial pressure is required to remove the folds and creases to a sufficient degree to insure that an accurately spherical reflecting surface will result. Even if such pressures are produced, they are easily dissipated when the envelope is punctured by micrometeorite collisions and cannot be expected to maintain the spherical form for any extended period.

Another proposal heretofore advanced involves the placing of an electrostatic charge upon the envelope sufficient to produce the required stresses therein. Calculation indicates, however, that the magnitude of this charge is such that it cannot be stored upon an envelope of any known material having the other required characteristics.

It is accordingly the object of the present invention to improve balloon-type passive repeaters and to provide practical means for inflating such repeaters to the desired form after they have been launched in orbit.

In view of the above objects, a satellite repeater, according to the invention, comprises a spherical envelope of metallized material adapted to be folded for transport into orbit. A diametral support member is provided, and motors mounted at the ends of the support member are arranged to provide angular torques about the longitudinal axis of the member to spin the folded envelope with sufficient velocity to cause it to assume the desired spherical form. Compressive stresses acting in the envelope in the vicinity of the ends of the spin axis so provided cannot be supported by the envelope itself. Accordingly, segmental caps of rigid material are mounted on the support member and are of sufficient height to overlie those portions of the envelope placed in compression. These caps are secured to the portions of the envelope which they overlie, at least along the peripheral edges of the caps. Thus the collapsed satellite envelope may be spun into and maintained in spherical shape, and sufficiently large stresses may be built up in the envelope to remove folds and creases therefrom to any desired degree.

The above and other features of the invention will be

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considered in the following specification taken in connection with the drawing in which:

FIG. 1 is a side elevation of a space satellite vehicle according to the invention;

FIG. 2 is a partial side elevation of the vehicle of FIG. 1; and

FIG. 3 is a vector diagram explanatory of the various forces acting upon the satellite of FIG. 1 to produce the desired spherical form of the envelope.

The satellite vehicle, according to the invention, is shown schematically in FIG. 1 as it would appear after erection in orbit and inflation of the envelope. Basically, the vehicle comprises a spherical envelope 10 which may be made of mylar or other thin film or fabric which is treated to provide a metallized or other surface capable of reflecting radio waves. This envelope is secured to a diametral tube 12, made of rigid material about which the envelope may be folded when in a collapsed state for transport within a rocket from a launching site to the desired orbit. If desired, diametral tube 12 may be arranged to telescope so that the over-all length of the rocket payload may be decreased. When such a satellite is launched in orbit, the problem of causing the folded envelope to assume the spherical shape which will enable it to act as an isotropic reflector of radio waves is resolved by spinning the vehicle about the longitudinal axis of tube 12. Such a spin of the vehicle about this axis is conveniently produced by paired jets 14 and 16 mounted to exhaust gas stored in tanks 18 and 20, respectively, in directions generally tangential to the circumference of tube 12. As shown in FIG. 1, these tanks are mounted near the ends of the tube and are located within the envelope when the latter is inflated. It is obvious, however, that the tanks may be mounted exteriorly if that particular arrangement would result in a more compact over-all package. The control of jets 14 and 16 may be accomplished by a radio system or by timing means actuated when the satellite is released from the transporting vehicle. In any event, the object is to spin the satellite about the axis of tube 12 with sufficient angular velocity to produce circumferential forces of sufficient magnitude to inflate or distend the collapsed envelope. It is obvious that such forces can be so produced but it is less obvious that this method of inflation of the envelope, without more, cannot succeed because of the compressive forces exerted upon the envelope at the vicinity of the ends of the tube 12. Means are provided, according to the invention, for eliminating this difficulty.

A coordinate system useful in analyzing the spinning relay structure is shown in FIG. 3 of the drawing. Here, the axis of rotation is shown vertical and the meridional angle ϕ from the axis is taken as one coordinate while the angle of longitude θ is taken as the other. The dynamic loading at any point of the envelope is then the inertia force $\rho\omega^2r \sin \phi$, where ω is the angular speed of the shell and ρ its density per unit area. The equilibrium conditions for an element of the shell of the dimensions $d\phi$ and $d\theta$ are

$$a \frac{d}{d\phi} (N_\phi \sin \phi) - N_\theta a \cos \phi = -\rho\omega^2 a^3 \sin^2 \phi \cos \phi \quad (1)$$

in the meridional direction and

$$N_\phi = -N_\theta + \omega^2 a^2 \rho \sin^2 \phi \quad (2)$$

in the radial direction, where a represents the radius of the sphere. These equations express a membrane state of stress where the membrane forces are

N_ϕ = meridional stress

N_θ = circumferential stress

Shears obviously vanish due to the symmetry.

The solution of these equations is evidently

$$N_{\phi}=0$$

and

$$N_{\theta}=\omega^2 a^2 \rho \sin^2 \phi \quad (3)$$

As indicated above, a tensile stress is introduced in the circumferential direction. If support member 12 is taken as applying loads P at the ends of the axis of rotation a tensile meridional stress of magnitude $P/2\pi a \sin^2 \phi$ and a compressive circumferential stress of equal magnitude are produced. The total stress pattern in the sphere is then described by

$$N_{\phi}=P/2\pi a \sin^2 \phi \quad (4)$$

and

$$N_{\theta}=-P/2\pi a \sin^2 \phi + \rho \omega^2 a^2 \sin^2 \phi \quad (5)$$

N_{θ} is seen to be compressive near each end of the axis of rotation and changes to tension at

$$\phi_0 = \sin^{-1} \left[\frac{P}{2\pi \rho \omega^2 a^3} \right]^{1/4} \quad (6)$$

Since the envelope standing alone is incapable of carrying any compressive stress means must be provided for performing this function. As shown in FIG. 1, such means comprise a pair of caps 22 and 24 which are mounted at opposite ends of support member 12 and are formed as segments of the sphere corresponding to the inflated envelope. The height of these segments is such as to offer support to the envelope out to the angle ϕ_0 where the stress upon the envelope changes from compressive to tensile. This angle is given by Equation 6 above. These end caps may be formed of any material capable of supporting the compressive stresses although, as will appear hereinafter, they are conveniently of metallic material. Further, they may be formed of a plurality of sectors which may be folded together to save space and fanned out after the vehicle is in orbit to form the rigid support required. Obviously, those portions of the envelope which underlie caps 22 and 24 must be secured to the caps and this may be done by any convenient means. According to one method, for example, appropriate portions of the inner surfaces of the caps may be coated with a contact cement against which the envelope is forced when inflated.

It will be seen that through the use of caps 22 and 24, the conditions of Equations 4 and 5 are satisfied and the space satellite may be spun about the axis of support member 12 with sufficient angular velocity to cause it to assume a spherical form and, further, sufficient stress may be imposed upon the envelope to eliminate wrinkles or folds therein to any desired degree.

According to a further feature of the invention, support member 12 may take the form of a hollow tube extending diametrically through the inflated satellite body. Additional jets, shown as 26, 28, 30, and 32, may be provided for the exhaust of gases from tanks 18 and 20, jets 26 and 30, and 28 and 32 acting in pairs to produce thrusts in the same direction. Such thrusts may be employed with benefit when the passive repeater satellite is launched in the so-called twenty-four hour orbit so that it, in effect, remains stationary above one position on earth. It will be understood that if the radius of the orbit changes because of perturbations therein, the desired stationary position with respect to the earth will not be maintained. Corrective thrusts applied when the spin axis of the satellite is in the plane of the orbit and directed toward the earth will then serve to correct the radius. The hollow tube support member permits the use of gas from both of tanks 18 and 20 for the production of such corrective thrusts because jets from both tanks may act in concert, one directly and the other through the hollow support member. In addition, and as shown in FIG. 2 of the drawing, paired sets of radial nozzles or jets, such as jets 34 and 36, may also be provided at the ends of support member 12. Gas exhausted from tanks 18 or 20 by way

of such jets may be employed to provide corrections in the position of the vehicle.

In the above, it has been assumed that means are available for selectively operating any of jets 14, 16, 26, 28, 30, 32, 34, or 36 to provide various thrusts upon the satellite vehicle. Control of the operation of such jets may be accomplished over radio channels from a remote control station located, for example, on the earth. For this purpose, a radio receiver 38, providing a plurality of narrow band communication channels, may be mounted on support member 12 and conveniently disposed symmetrically with respect thereto. Receiving antennas for control signals radiated to the satellite may be mounted upon caps 22 or 24 or the caps themselves may be insulated from the surface of the satellite and serve directly as receiving antennas. Although shown only in schematic form, receiver 38 may be of any known variety of telemetry receiver and may be arranged to produce control signals for valves controlling the various jets referred to above. Such selective control systems are well known and need not be further described.

Alternatively, receiver 38 may be part of a transmitter-receiver unit and a second, and similar unit 40, may be mounted at the opposite end of support member 12. Caps 22 and 24 would then serve respectively as antennas for the two transmitter-receiver units and radiation from the two antennas could provide signals appropriate for use at a base station to determine the alignment of the vehicle. From such determinations at the base station, control signals could be produced for radiation to the vehicle to control appropriate ones of the exhaust jets.

Although appropriate design and the use of appropriate folding methods are believed sufficient to permit erection of the satellite envelope by the spin action described above, the possibility that the envelope might wrap around the support member during the initial spin phase may be eliminated by providing a gaseous charge which may be released temporarily to inflate the envelope to a sufficient degree to prevent this result. Conveniently, a small tank or container of gas 42 may be provided within the envelope and controlled by an additional channel of radio receiver 38 or otherwise to exhaust its contents within the envelope as soon as the satellite vehicle has been launched in orbit. Since other means are available to maintain the spherical form of the envelope and, in fact, to produce greater tensile stresses thereupon, it is of no significance that the gaseous charge originally employed may be dissipated through leakage produced by micrometeorite collisions or the like.

What is claimed is:

1. A space satellite comprising an inflatable spherical envelope of pliable material, an elongated support member of length equal to the diameter of said envelope when inflated, said envelope being adapted when collapsed to be folded about said support member, inflating means for said envelope comprising means for spinning said satellite about the longitudinal axis of said support member to produce circumferential tensile stresses upon said envelope, and means for compensating compressive stresses applied to said envelope by the spin of the satellite about said axis.

2. A space satellite for use as a communications repeater comprising a spherical envelope of pliable material capable of reflecting radio waves, an elongated support member of length equal to the diameter of said envelope when distended, said envelope being adapted when collapsed to be folded about said support member, means effective after said satellite is launched in orbit to produce circumferential tensile stresses upon said envelope in planes normal to said support member, and means for compensating compressive stresses produced in other portions of said envelope by the last-mentioned means.

3. A space satellite for use as a communications repeater comprising an inflatable spherical envelope of pliable material capable of reflecting radio waves, an elon-

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gated support member of length equal to the diameter of said envelope when inflated, said envelope being adapted when collapsed to be folded about said support member, means for spinning said satellite about the longitudinal axis of said support member after it is launched into orbit, and caps, comprising segments of the sphere occupied by the envelope when inflated, mounted on the ends of said member and secured to the underlying portions of said envelope, said caps being of diameter sufficient to overlie such portions of said envelope placed in compression by the spinning of said satellite about said axis.

4. A space satellite for use as a communications repeater comprising an inflatable spherical envelope of pliable material capable of reflecting radio waves, an elongated support member of length at least equal to the diameter of said envelope when inflated, said envelope being adapted when collapsed to be folded about said support member, propulsion means mounted outside the envelope for spinning said satellite about the longitudinal axis of said support member, and caps, comprising segments of the sphere occupied by the inflated envelope, mounted on said support member at a separation equal to the diameter of said sphere and secured to the underlying portions of said envelope, said caps being of diameter sufficient to overlie such portions of said envelope placed in compression by the spinning action of said propulsion means.

5. A space satellite for use as a communications repeater comprising an inflatable spherical envelope of pliable material capable of reflecting radio waves, an elongated support member of length equal to the diameter of said envelope when inflated, said envelope being adapted when collapsed to be folded about said support member, means for initially producing at least a partial inflation of said envelope after the satellite is launched into orbit, means for subsequently spinning the satellite about the longitudinal axis of said support member, and means for compensating for compressive forces acting on the envelope in the vicinity of the ends of said elongated member when the satellite spins about said axis.

6. A space satellite for use as a communications repeater comprising an inflatable spherical envelope of pliable material capable of reflecting radio waves, an elongated support member of length equal to the diameter of

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said envelope when inflated, said envelope being adapted when collapsed to be folded about said support member, means for spinning the satellite about the longitudinal axis of said support member, means for compensating for the compressive stresses applied to portions of said envelope by the spinning of said satellite, and means mounted on said elongated member inside the extended envelope of the satellite for producing orbit-correcting thrusts in the direction of the longitudinal axis of said support member.

7. A space satellite for use as a communications repeater comprising an inflatable spherical envelope of pliable material capable of reflecting radio waves, a diametral hollow tube serving as a support member about which said envelope may be folded when collapsed, motors mounted on said tube within the limits of said spherical envelope when inflated to produce tangential forces to rotate said tube about its longitudinal axis and to align this tube with respect to the earth, thrust devices mounted inside said tube and arranged to act in concert selectively to produce thrusts in either direction along the axis of said tube, and means for compensating for compressive forces acting upon said envelope in the vicinity of the ends of said tube upon spinning of the satellite about said longitudinal axis to extend said envelope.

8. A space satellite for use as a communications repeater comprising an inflatable spherical envelope of pliable material capable of reflecting radio waves, a diametral hollow tube serving as a support member for said envelope when extended, a supply of gas, jets mounted at the ends of said tube, extending, respectively, radially and tangentially thereto, other jets mounted within said tube and directed along the longitudinal axis thereof in opposite directions, a further jet communicating with the interior of said envelope, and means acting after said satellite has been launched into orbit for directing gas from said supply to said further jet partially to inflate said envelope, thereafter to said tangentially extending jets to produce spinning of the satellite about the longitudinal axis of said tube to cause extension of said envelope to spherical shape and selectively to said other jets for applying alignment and orbit-correcting thrusts to said longitudinal axis.

No references cited.