March 8, 1966 J. BANCHE ETAL 3,239,839

ANTENNA REFLECTOR SURFACE CONTOUR CONTROL

Filed April 11, 1963 2 Sheets-Sheet 1

Fig. 1

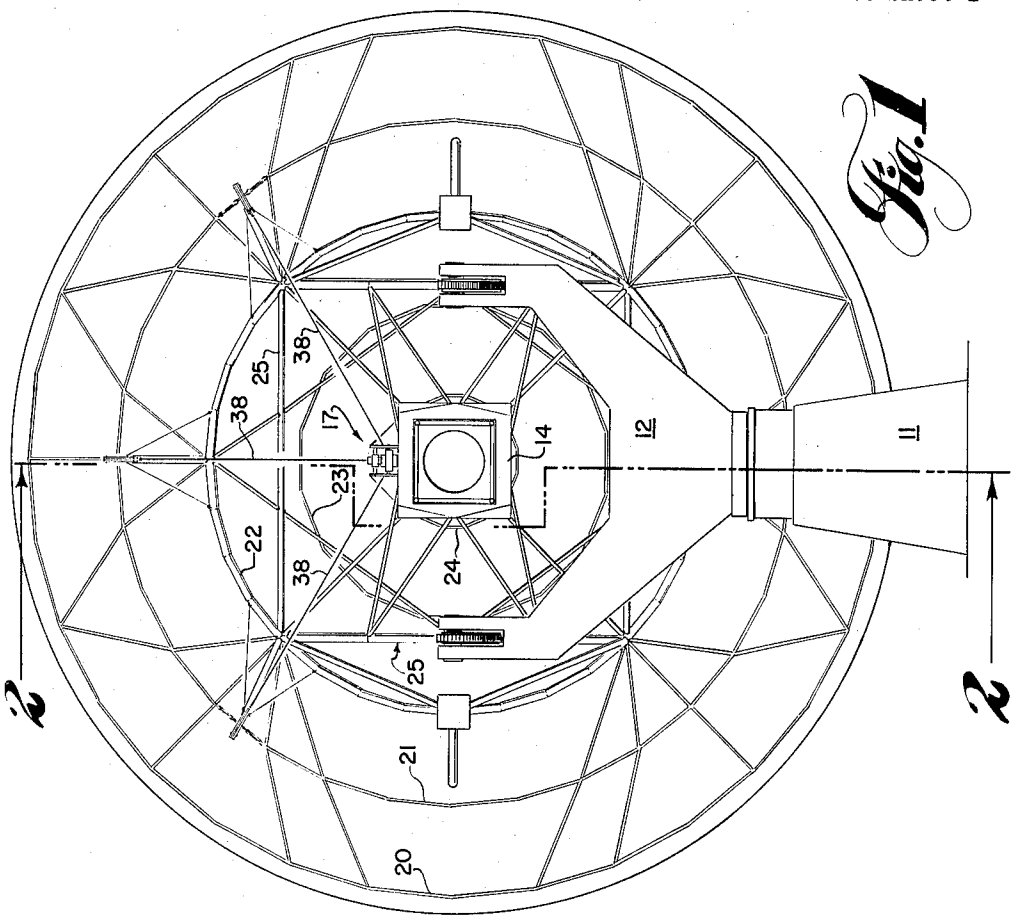
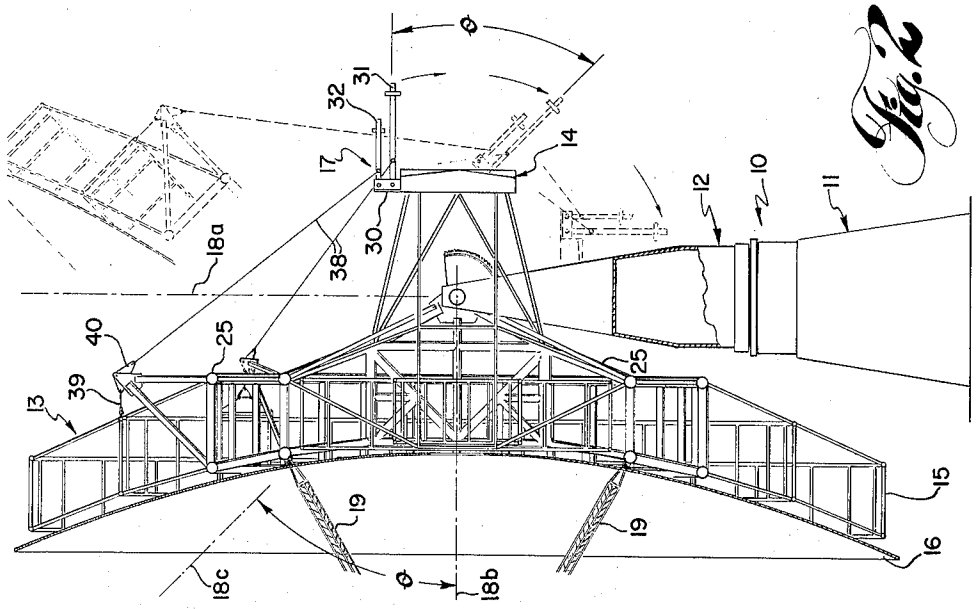


Fig. 2



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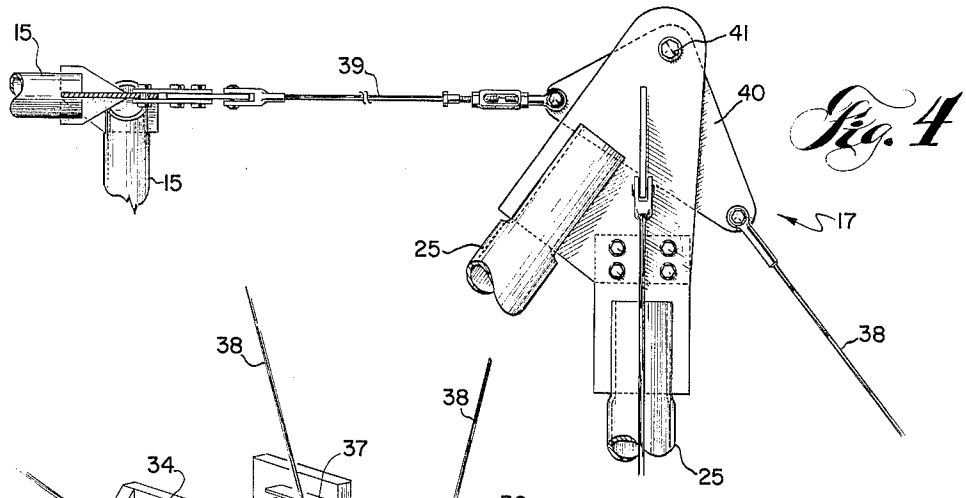


Fig. 4

Fig. 3

Fig. 5

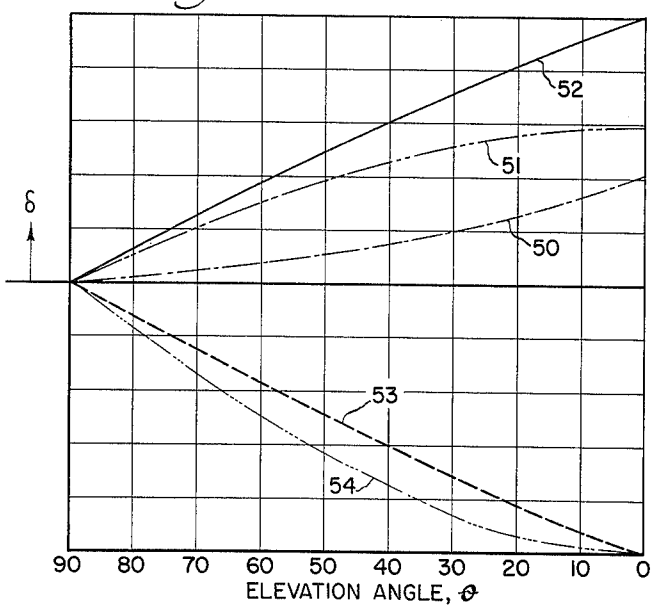
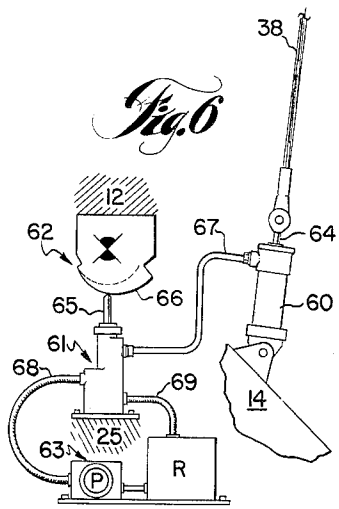


Fig. 6



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3,239,839

ANTENNA REFLECTOR SURFACE CONTOUR CONTROL

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4 Claims. (Cl. 343—915)

This invention relates to a ground-based precision antenna system having a large-diameter reflector and especially concerns novel means for effecting contour control in the surface portion of the large-diameter reflector used in such system. Antenna systems of the type hereindisclosed are particularly useful in connection with scientific investigations of the ionosphere, emissions from planetary atmospheres, solar corona effects, and various phenomena and problems encountered in navigation, communications, and the like. The invention described and claimed herein has found particular utility in connection with the use of radio equipment having operating capabilities at frequencies up to 10,000 megacycles per second.

Although a ground-based precision antenna system typically employs other major equipment items in addition to a large-diameter primary reflector surface, this invention is essentially concerned with the principal energy-reflecting surface contained therein. In order that precision quality and operability be maintained in the antenna system it is necessary to provide a primary reflector construction which obtains an optimum minimization of both surface deflection and total weight throughout a comparatively wide range of surface operating positions. During operation of a typical precision antenna having a large-diameter reflector, the reflector system components are often rotated together through an elevation angle of approximately 90° and through an azimuth angle of approximately 360°. Unncessary or improperly distributed weight in the reflector can be the source of excessive surface deflections which result in unsatisfactory system performance. The use of additional material to develop further rigidity in the reflector structure may be the cause of undesirable system tracking inertia and also tends to compound the deflection problem. System performance penalties which cannot be tolerated may thereby be incurred.

The invention detailed and claimed herein has found utility in connection with an antenna system having a primary reflector designed with a diameter of approximately 120 feet and weighing approximately 70,000 pounds. The maximum permissible surface deviation of the primary reflector from a true paraboloid for all operational conditions was not to exceed ±0.075" when measured essentially parallel to the reflector axis. The maximum deviation of any point in the reflector with respect to the theoretical or desired reflector surface position was found to be approximately ±0.072". This deviation was a net value based upon the most adverse effects of deflection, temperature, and fabrication and placement tolerances.

The net gravity deflection at any point in the reflecting surface of an antenna system large-diameter reflector that rotates in elevation is the resultant of the deflections at that point caused by symmetrical dead-weight loadings and by anti-symmetrical dead-weight loadings, and that resultant deflection varies in magnitude as a function of the reflector elevational angle at particular positions. Accordingly, an antenna system reflector may advantageously be provided with surface deflection compensation means responsive to reflector elevational angle changes to thereby effect better reflector performance and improved reflector surface contour control throughout the reflector elevational range.

A primary object of this invention is to provide an antenna system primary reflector with an improved surface contour control capability.

Another important object of our invention is to provide an antenna system primary reflector with surface deflection compensation means that responds as a function of the antenna reflector elevational angle.

A still further object of this invention is to provide an antenna reflector with surface deflection compensation means that may be readily constructed into embodiments that utilize fixed-value gravitational forces only in achieving a reflector surface contour control as the antenna reflector is moved throughout its elevational range.

Other objects and advantages of this invention will become apparent during a consideration of the description and drawings of this application.

In the drawings:

FIG. 1 is a rear elevational view of an antenna system which incorporates a preferred embodiment of our invention;

FIG. 2 is a sectional view taken generally along line 2—2 of FIG. 1;

FIG. 3 is a perspective view of a portion of the deflection compensation means incorporated in the primary reflector of the antenna system of FIGS. 1 and 2;

FIG. 4 is a detail elevational view of another portion of said deflection compensation means;

FIG. 5 provides a graphical presentation of antenna reflector actual surface deflections and desired compensation deflections as a function of antenna reflector elevational angle; and

FIG. 6 is a schematic illustration of an alternate form of the deflection compensation means of our invention.

The major components of a Cassegranian-type antenna system **10** illustrated completely in FIG. 1 and partially in FIG. 2 are: base **11**, elevation-azimuth mount **12**, primary reflector **13**, and ballast or counter-weight means **14**. Primary reflector **13** is essentially comprised of primary backup structure **15** and contoured reflecting surface **16**. Means for effecting antenna reflector deflection compensation and improved surface contour control as a function of the primary reflector elevational angle is referenced generally as **17** in such figures. The form of deflection compensation means illustrated in FIGS. 1 through 4 of the drawings makes use of fixed-value gravitational forces for achieving the desired end results. Mechanically powered means in the form of hydraulically-loaded actuators and command elements which respond to the antenna system elevational angle are shown as an alternate embodiment of this invention in FIG. 6. Also, this invention has application to large-diameter reflectors incorporated in antenna systems of other than the Cassegranian-type.

In the drawings, the various reference lines for the antenna system are designated by the numeral **18**. In all positions of the antenna, reference line **18** corresponds to the radio-frequency axis of the system. Referring to FIG. 2, the antenna is considered in its zenith position when the radio-frequency axis corresponds to line **18***a* and is in a true vertical condition. **18***b* designates the position of the antenna radio-frequency axis when the system is in a true horizontal or face-forward condition. **18***c* designates an intermediate position which is $\theta°$ from the position of **18***b*. The angle θ is measured from **18***b* only for convenience. It also relates to the FIG. 5 graphical analysis of experienced antenna reflector load deflections and effected compensation deflections.

Portions of a quadripod structure **19** that supports the Cassegranian-type antenna system secondary reflector are shown in FIG. 2. Both the reflector backup structure and reflector surface portions (**15** and **16**) of the system are generally symmetrical about the radio-frequency axis **18**. In the illustrated antenna system, five concentric

truss-type ring beams **20** through **24** are connected to each other by inter-ring tension members (not shown). The secondary or auxiliary backup structure **25** carries reflector portions **15** and **16** and is basically provided to efficiently restrict the distortion of those reflector portions as normally caused by anti-symmetrical gravitational loadings. Additional details regarding the inter-ring tension members and the extent of secondary backup structure **25** are provided in U.S. Patent No. 3,105,969, issued October 1, 1963.

FIGS. 3 and 4 provide details regarding the deflection compensation means **17** incorporated in the antenna primary reflector and illustrated generally in FIGS. 1 and 2. Such deflection compensation means includes a support bracket **30** which is rigidly coupled to ballast **14** and variably-loaded lever members **31** and **32** which are carried by and rotatable relative to bracket **30** through connectors **33** and **34**. Such connectors serve as the rotational axis for the lever members. Each lever member carries a fixed weight assembly **35** or **36** to establish the basic magnitude of desired deflection compensation forces. Suitable means are also provided, but not referenced, for conveniently adjusting or changing the position of the weight assemblies relative to rotational axes **33** and **34**. However, changing the size or position of the weight assemblies does not change the basic quality or function of the deflection compensation means.

Each lever member carries one or more connector devices **37** for coupling the gravity compensation forces developed by the lever member to other portions of the deflection compensation means and to antenna reflector surface **16**. Other coupling means consists of cables **38** and **39** and bellcranks **40**. Bellcrank **40** is rotatably connected to the reflector secondary backup structure **25** by connector means **41**. Cables **38** may be connected to bellcranks **40** using conventional clevis-type fastener devices. Cables **39** may be coupled to bellcranks **40** and to primary backup structure **15** by conventional clevis-type fastener devices also. It should be noted that the desired deflection compensation forces which originate with the disclosed lever and weight members are transmitted into backup structure **15** and connected surface **16** so as to be applied in a direction parallel to radio-frequency axis **18**. To achieve this object it is only necessary that cable components **39** be oriented parallel to that radio axis. Undesired components of the reaction forces present at connector **41** are preferably transmitted into selected components of secondary backup structure **25** where they will have a minimum effect on antenna surface deflection.

The gravitational forces applied to weight members **35** and **36** and components attached thereto cause rotational moments in lever members **31** and **32** about axes **33** and **34** and at all reflector positions other than true zenith. The reaction moments thereto are transmitted into the various cables **38**. If desired, pre-load forces may be induced into compensation means **17** by tensioning cables **38** when reflector **13** is in its zenith position. It should be noted that the locations for attaching cable members **39** relative to backup structure **15** and surface **16** and the desired weight values and moment arms for deflection compensation means **17** may be selected and determined by conventional mathematical analysis of the reflector structure. As will be developed in the discussion of FIG. 5, the positioning and location of the various components does not alter the functional characteristics of deflection compensation means **17**.

In FIG. 5, we have graphically illustrated the relation of various reflector deflection components and desired compensation forces. The abscissa values given on the graph correspond to the angle θ of FIG. 2. No units are specified for the deflection ordinates. Curve **50** plots antenna reflector surface deflections caused by anti-symmetrical gravitational loadings as the reflector portion of the antenna system is rotated through its elevational range. Such deflections are equal to the deflections associated with the true horizontal position (radio-frequency axis **18***b*) as a function of 1-sine θ. Curve **51** plots antenna reflector surface deflections caused by symmetrical gravitational loadings as the system is rotated through its elevational range. Such deflections are equal to the deflections associated with a true vertical or zenith position (radio-frequency axis **18***a*) as a function of cos θ. Curve **52** represents the dead-weight deflection sum of curves **50** and **51**. Curve **53** is the negative of curve **52**, plots the desired compensation deflection, and is representative of the changing deflection compensation force that should be introduced into the antenna reflector primary backup structure and surface as the system is rotated to the various indicated elevation angles. The desired net deflection compensation force as noted approaches being a linear function of the system elevational angle. In practice, each point on the reflector surface behaves according to such relationships though generally having different deflection amplitudes. It generally suffices to match the deflection compensation system of our invention to the more significant points of surface deviation although the means may be extended to include surface points of secondary interest.

We have provided an extremely reliable and comparatively simple means for improving the reflecting surface contour control capability of a large-diameter antenna reflector as the incorporating antenna system is rotated in elevation throughout a substantial range. Gravitational forces alone may be utilized in developing satisfactory compensation. In the zenith position lever members **31** and **32**, for instance, are often supported entirely by the antenna ballast **14** and no compensation forces are developed for transmission through cables **38** and **39** and bellcranks **40** into the antenna primary backup structure **15** or reflector surface **16**. As the antenna is rotated to its full face-forward position or to intermediate positions, the desired compensation force for particular points is developed in lever means **31, 32**. The weight value for each lever member remains fixed throughout antenna operation; however, the effective value of the moment arm applying the compensation force developed from gravitational forces acting on weight assemblies **35, 36** varies as a function of the reflector elevational angle and reaches a maximum value when θ equals 0°. The so-developed and so-applied deflection compensation forces will follow curve **54** according to a 1-sine θ function, are non-linear relative to elevational displacement of the reflector, and are sufficiently close to the curve **53** function for all antenna reflector positions so as to develop the desired reflecting surface contour control capability.

An alternate form of deflection compensation means **17** utilizing the features of our invention is illustrated schematically in FIG. 6. The arrangement of this illustration employs a mechanically-powered system to achieve the results associated with the deflection compensation means **17** of FIGS. 1 through 4. Referring to FIG. 6, an actuator **60** powered by pressurized hydraulic fluid is installed in series in each cable **38** to develop tension forces intermediate fixed structure such as ballast **14** and the movable bellcrank **40**. A potentiometer-type hydraulic valve **61** is employed to control the fluid pressure to actuator means **60**. The command signal for control of valve **61** originates with the cam member designated **62**. A conventional source of pressurized hydraulic fluid is designated generally as **63** and is basically comprised of a properly connected pump P and reservoir R. Actuator **60** has a rod or jack stem **64** which is movable by a connected piston element or the like in actuator **60** to change the stress induced in cable **38**. A movable sensor element **65** contacts the surface **66** of cam **62** and is connected to the valve spool of potentiometer-type hydraulic valve **61**. Cam **62** is fixed to support structure **12** so that during antenna system op-

ation the antenna reflector and other components of the FIG. 6 form of deflection means **17** rotate relative thereto. The indicated center of cam **62** corresponds to the elevational axis of rotation for the antenna system. The surface **66** of cam **62** is generally made to depart from a circular circumference condition throughout an elevational range of approximately 90° to give a true linear function of the antenna elevational position or to give a function corresponding identically to curve **53** or curve **54** of FIG. 5. Thus, surface **66**, in combination with the other elements shown in FIG. 6, provides the same improved reflecting surface contour control capability characteristically associated with previously-described lever members **31** and **32** and the weight assemblies carried thereby. Hydraulic fluid pressurized as a selected function of the antenna reflector elevational angle through valve **61** and cam **62** cooperation is ported to actuator **60** by means of the hydraulic fluid line designated **67**. The supply and return hydraulic fluid lines between valve **61** and the pump reservoir combination designated **63** are comprised of hydraulic lines **68** and **69**. It may be required that the latter hydraulic lines be provided with a flexible construction. This is for the reason that valve **61** is mounted rigidly relative to reflector backup structure **25** whereas the hydraulic system power components **63** may be located in a fixed position in the manner of cam **62** on mount **12**. In either event, the components of the FIG. 6 arrangement may be readily provided to function with the same end results achieved by the form of our invention illustrated in FIGS. 1 through 4.

It is to be understood that the forms of the invention herewith shown and described are to be taken as preferred embodiments of the same, but that various changes in the shape, size, number, and arrangement of parts may be resorted to without departing from the spirit of the invention or the scope of the subjoined claims.

We claim:

1. In an antenna system:

(a) a contoured reflecting surface having a radio-frequency axis and having a surface point which is deflected from an established reference point in a direction parallel to said radio-frequency axis when the reflecting surface is rotated in elevation from a position with said radio-frequency axis in a vertical condition,

(b) primary backup structure fixedly connected to and providing support for said reflecting surface,

(c) secondary backup structure fixedly connected to and providing support for said primary backup structure,

(d) separate means cooperating with said secondary backup structure and originating a deflection compensation force which varies in magnitude from a minimum value when said reflecting surface is positioned with said radio-frequency axis in a vertical condition to a maximum value as a function of the angular displacement of said radio-frequency axis from said vertical condition, and

(e) cable means connected to said separate means and to said primary backup structure and transmitting said deflection compensation force from said separate means to said primary backup structure in the region of said surface point,

said secondary backup structure being relatively stabilized against deflection in comparison to said primary backup structure, and said cable means applying said compensation force to said primary backup structure along a direction which is parallel to said radio-frequency axis.

2. The antenna system defined by claim **1**, wherein said separate means consists of a lever member rotatably supported by said secondary backup structure at a rotational axis, and weight means connected to and carried by said lever member a distance from said lever member rotational axis, said lever member and weight means developing a moment about said lever member rotational axis that originates said deflection compensation force and that varies as a 1-sine θ function as said reflecting surface, primary backup structure, and secondary backup structure are rotated together from said radio-frequency axis vertical condition, θ being the complement of the angular displacement of said radio-frequency axis from said vertical condition.

3. The antenna system defined by claim **1**, wherein said separate means consists of a movable valve member linearly controlling the force loading of a hydraulic actuator connected in force-originating relation to said cable means, and a cam surface engaging and controlling the movement of said valve member, said cam surface varying in distance from the rotational axis of said secondary backup structure as a linear function of the angular displacement of said radio-frequency axis from said vertical condition.

4. The antenna system defined by claim **1**, wherein said secondary backup structure includes fixedly connected counter-weight means at a side opposite to said primary backup structure and said reflecting surface, said separate means developing a reaction force opposite to said deflection compensation force at said counter-weight means.

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