September 26, 1962

Dr. Geoffrey Keller
National Science Foundation
Washington 25, D.C.

Dear Dr. Keller:

In accordance with our conversation of September 12th, I have drawn up a proposal entitled "Steerable Parabolic Radio Telescope." Twenty copies are enclosed herewith.

Soon I am leaving for Australia. Any further correspondence should be addressed to me at

C.S.I.R.O.
Stowell Avenue
Hobart, Tasmania, Australia

Sincerely yours,

Grote Reber

Grote Reber

GR:E
Enclosures

STEERABLE PARABOLIC RADIO TELESCOPE

By Grote Reber

Starting Date: 1st January 1963

Completion Date: 31st December 1963

Synopsis

The proposed research is primarily an experiment in civil and mechanical engineering. The finished models will be operative mechanically. These will be working hardware in form of building blocks for a successful radio telescope of novel design at a future date.

Introduction

The important part of a dish type radio telescope is the surface of the paraboloid. At centimeter waves the effective surface is less than a thousandth of an inch in depth. All the rest of the structure is present merely to hold the skin surface in the desired position or move it about. On most designs the ratio of material in the skin/structure is very low and becomes increasingly poor as the size of structure increases. The primary difficulty in past designs is caused by too few support points.

Design Principles

A well-known engineering principle states that large structures should have many supports. The multiplicity of columns in a skyscraper is an example. Similarly, large moving objects should have many rolling supports, such as a ten thousand ton freight train.

When the solid angle is a spherical radian, or less, the surface of a paraboloid of revolution closely approximates that of a sphere. The focal length of parabola will be one-half the radius of sphere. The proposed design uses a movable paraboloid inside a part spherical hole in ground. Motion in azimuth is secured by concentric circular horizontal tracks fastened to inside of spherical surface. Motion in elevation is secured by parallel circular vertical tracks fastened to back of paraboloid. A support point will occur at each place these two systems of tracks intersect. Each support point or bogie will consist of two wheels, one above the other. The lower wheel will run upon a track inside the spherical surface. The upper wheel will run under a track on back of the paraboloid. The bogies will be maintained in proper position by a network or web of spacing members. The web will be somewhat larger than mirror. See the three drawings. Each vertical track under mirror frame must always intersect two or more horizontal tracks in hole. After the drawings were made it became apparent that this condition will not hold for the outside vertical tracks. Consequently, at least one more horizontal track will have to be added to those shown.

The parabola will have least potential energy when at bottom of hole in ground. As parabola rises up side of hole, a system of tapered counterweights will descend along suitable guides in the web. The arrangement is quite similar to counterweights on an elevator which keep the potential energy of empty system zero independent of the position of elevator. Nothing equivalent to varying load of elevator will be present on moving parabola.

If every wheel is appropriately driven the entire web and parabola assembly will lack internal forces and float upon the horizontal tracks in hole. Likewise, the counterweight fastenings will be dispersed over back of parabola to remove internal forces. By these measures, the material in web and frame of parabola may be reduced to a very small amount.

The surface of parabola will be foam plastic panels covered on both sides with invar foil. Most of the strength and rigidity is due to the foil which also prevents buckling when two sides of panel have different temperatures. The deformation of such panels caused by position changes is about two orders of magnitude less than an equal weight panel of steel plate or mesh. Consequently, large panels may be used with a great reduction in frame material.

Temperature Variation

The temperature coefficient of expansion of rock is appreciable. However, the thermal conductivity of earth is very low. Consequently, the temperature of rocks a few feet below the surface is nearly constant from day to night and summer to winter. This is particularly true in climates free from prolonged freezing. The length of supports from back of dish to rock is only a few feet in all cases. Consequently the dish is effectively mounted on and mechanically tied to immovable rock. This feature eliminates major temperature deformation of the structure.

At times the hole may cast a shadow across part of dish. On a clear day the sunlit part of dish and web may be at a much higher temperature than part in shadow. This will cause differential expansion and distortion of size. However, the web and frame of mirror are constrained by the fixed shape of hole. Effectively this holds dish to the desired parabolic shape but allows the web and frame to have different boundary compared to uniform temperature. The panels will remain of fixed size due to properties of foil and porous filling between. Variation in size or shape of frame will appear as variations in cracks between panels. The cracks are to be filled with a flexible strip for electrical conductivity.

The focal point of parabola will be located by a three-leg parapet. Each leg is to be a hollow double conical spar largest at center. Nonmetallic material may be advantageous in respect to weight, rigidity and electromagnetic wave scattering. Along the center of spar and constrained thereto by crosswise guides will be an invar wire under a fixed tension determined by a spring at bottom. The wire will run through center of an electrically operated jack at bottom of spar. If the mirror position changes so that load on end of spar increases, the length of spar will decrease; tension on spring will decrease; jack will wind-out sufficient to bring tension on spring back to original value. If the material of spar expands when sun warms parapet, the spar length increases; jack will wind-in sufficient to bring tension on spring back to original value. The length of wire and spring will thus remain constant irrespective of position or temperature of parapet. A fixed focal point is thereby secured.

Sky Coverage

The maximum zenith angle is proportional to the ratio of diameter's hole/mirror and to the amount mirror is allowed to project above edge of hole. When this ratio is about 1.5 and projection about 0.1 of mirror diameter, the maximum zenith angle is about 50 degrees. This matter has been discussed in greater detail with sketches by me in a report entitled "Large Mirror Design," 15th March 1955, Associated Universities publication code A-14-1.

Equatorial Mounting

The instrument described above will be equatorially mounted when situated at the terrestrial poles. The equatorial feature will be maintained if the axis of circular tracks in the hole equals the latitude of the observer. In this case the axis of these tracks is always the polar axis.

Such equatorial mounting has some superficial advantages as no axis converter is necessary and the drive mechanism simplified. However, the range of motion of the dish is constrained. Also severe mechanical problems are encountered in holding the frame of dish onto the web and the web onto the lower tracks when pointing off the meridian.

Such a design might be a good civil and mechanical engineering exercise after an altiazimuth design has been perfected.

Proposal

The three main features of design are to be tested by three appropriate models.

(a) A plastic and metal dish about 3 ft. diameter operating in a hemisphere 5 ft. diameter. It is to be complete with counterweights and demonstrate the over-all design.

(b) A sample spar about 60 ft. long with invar wire and servo controlled jack. This is to demonstrate constancy of length with changes in temperature and load.

(c) A sample panel about 6 by 12 feet with invar foil surfaces and polyfoam center. This is to demonstrate lightness and constancy of surface with changes in temperature and position.

These models are to be constructed at Hobart, Tasmania, Australia, because of the convenience to other work now in progress. The industrial facilities of Hobart will provide about 80 per cent of the necessary material. Most of the rest will come from the mainland. Only a few per cent need to be imported. All design, procurement, construction supervision and financial arrangements will be by me. The cost estimate is about four thousand pounds equal nine thousand dollars. The funds are to be turned over to me, which eliminates all useless middlemen. They cannot buy or pay anything without my approval and merely get in the way of progress. After these three fundamental propositions have been demonstrated to my satisfaction, I will be in a position to undertake a fairly large model with reasonable certainty of success.

Future

During 1959 the elements of a design for a 1000-foot dish in a 1500-foot hole were organized by me while working at Green Bank. This was discussed before an NSF meeting late that year. Such design was merely to see what could be done and not a proposal to carry out the work. There seemed to be no problems related to the tracks, web or dish. These are limited only by size of hole. Apparently a dish a mile in diameter with more limited zenith angle coverage could be readily built. However, before 1000 ft. diameter is reached the problem of spars to support the focus becomes acute. Some type of aircraft guided by three or four modulated light beams might be invoked. Correspondence has been had with Lawrence Laboratory about excavating large holes. This can be done cheaply and in a manner relatively free from radioactive contamination. However, such matters are little better than speculation at present.

Practically, the place to start is an 85-foot model. When the detail problems are learned and solved, then a 250-foot sample could be built. Still later, a 700-foot dish could be constructed in the hole at Arecibo, Puerto Rico.

Comparison with Fixed Dish

The instrument being constructed at Arecibo is a fixed spherical mirror. The focus is a line instead of a point. This makes the focal apparatus very large and cumbersome. Also the frequency bandwidth is severely limited by the electrical problems of a long feed line focus. While a 1000-foot aperture is claimed, this is only available at the zenith. At 20 degrees zenith angle the loss is 3DB, which amounts to half the surface. This situation deteriorates rapidly as the zenith angle increases. The peculiar oblong shape of the resultant surface will give a nonsymmetrical beam shape with probably high side lobes at unpredictable angles. When pointing off the zenith the focus intercepts a lot of ground scatter. The useful surface is only a small part of the total surface which must be paved. The accuracy of the paved surface for any given wavelength must be just the same whether fixed or movable. Consequently, the same amount of framing per unit surface area is necessary. The required motion of focal line is such that a simple tripod parapet cannot be used. Resort must be had to a complicated and flimsy network of flexible wires. On every count, the fixed spherical dish is a poor second to a properly mounted true paraboloid of revolution.

Comparison with Gain Exchanging Systems

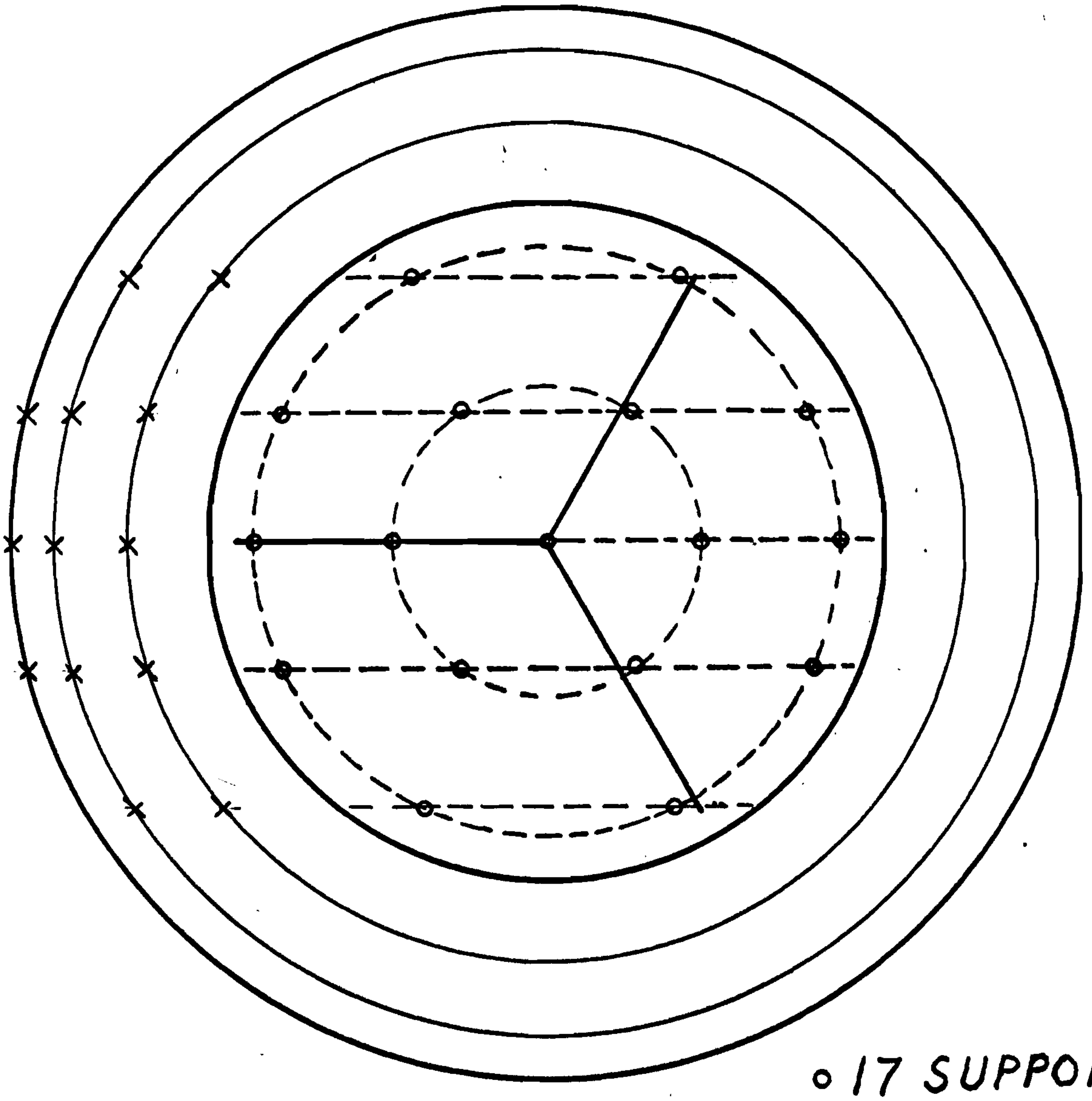
All gain exchanging schemes so far proposed are tied to the ground and provide only meridian transit observations. At high resolution, the time the radio source is in the beam may be so short that the equipment cannot react to a feeble source. Consequently much information is lost. This appears to be part of the reason why the 85 mc survey using a cross at Sydney provides such blurred pictures when compared to 408 mc survey using the Parkes dish. Both surveys had equal resolution. However, the major part of the deficiency of detail is simply that so much gain was exchanged to secure economy that the major part of the available information was eliminated. Only a filled-in aperture can provide the full possible celestial information.

Spectrum análysis and phenomena having intensity varying with time require a tracking type radio telescope.

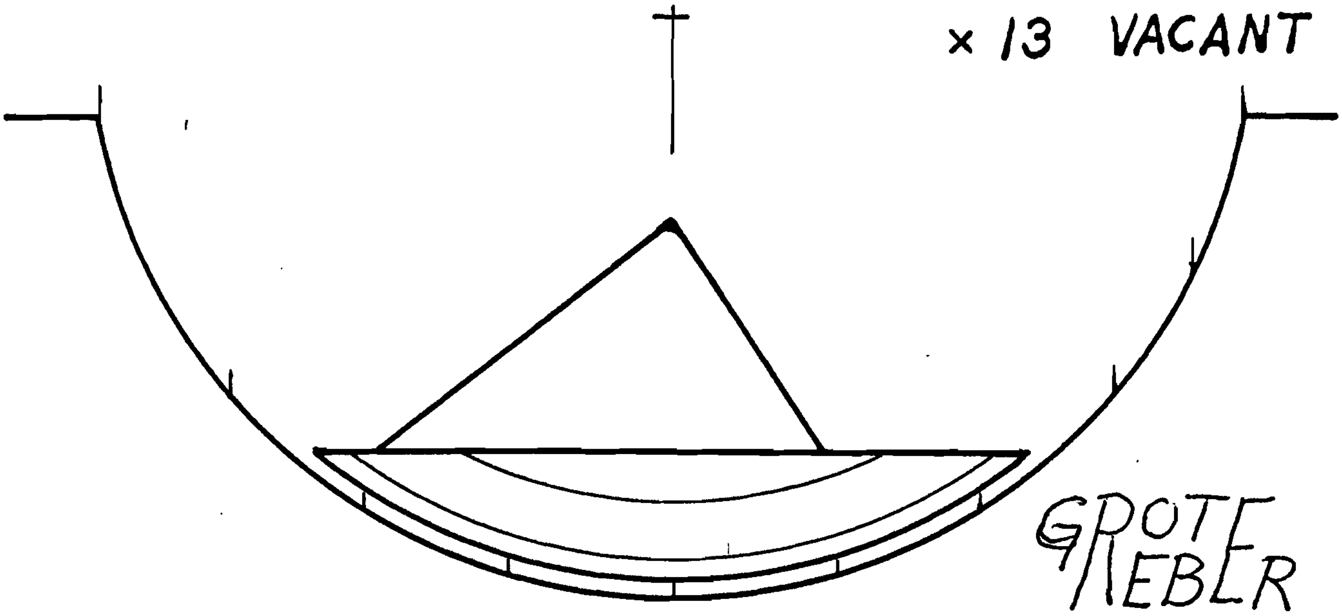
GROTE REBER

G. Reber
9/26/62

0° ZENITH ANGLE



o 17 SUPPORTS
× 13 VACANT



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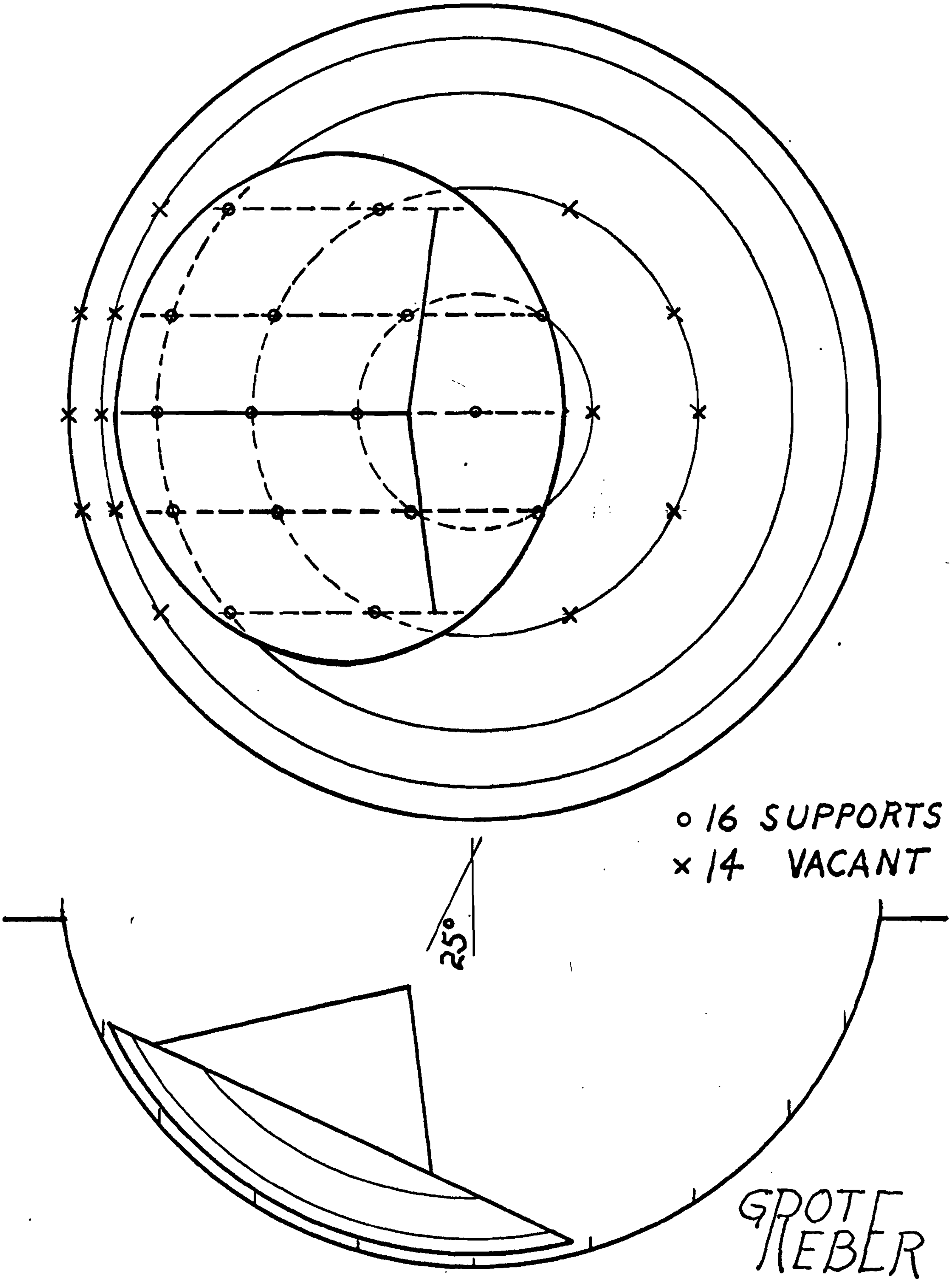
25° ZENITH ANGLE



GROTE REBER

50° ZENITH ANGLE