Some Suggestions for the VLA-Telescopes

S. von Hoerner Sept. 4, 1966

Summary

The following contains, first, three suggestions for structure and mount of the telescopes; second, some estimates about spherical and toroidal pannels; third, a suggested parabolic templet for adjusting the surface. All these suggestions are only of a tentative nature and should be worked out by an engineer.

The three telescope structures (called: one-point support, yoke, and cradle) seem possible and do not show any obvious difficulty. Only a cost estimate could tell which one is best and how it compares with more conventional, available designs. All three could be built for λ=1 cm just as easily as for 3 cm, since the gravitational limit (85 ft) is 5mm.

At average distance from the apex, spherical pannels could have a size of 8 by 8 feet, and 81 pannels are needed for an 85-foot dish and for λ = 3 cm wavelength. Toroidal pannels could have an average size of 21 by 12 feet, and only 24 pannels are needed. With 44 toroidal pannels 15 by 8 feet large, one could even go down to λ = 1 cm.

A parabolic templet for an 85-foot telescope, hanging from the focus, can be built with a weight of 500 lb; this replaces the weight of receiver and feed, and the templet thus gives no deformation to the telescope. Application is easiest if the feed support legs are outside the telescope surface; but if the legs do cut through the surface, a "folding" templet still can be used.

I. Structure and Mount

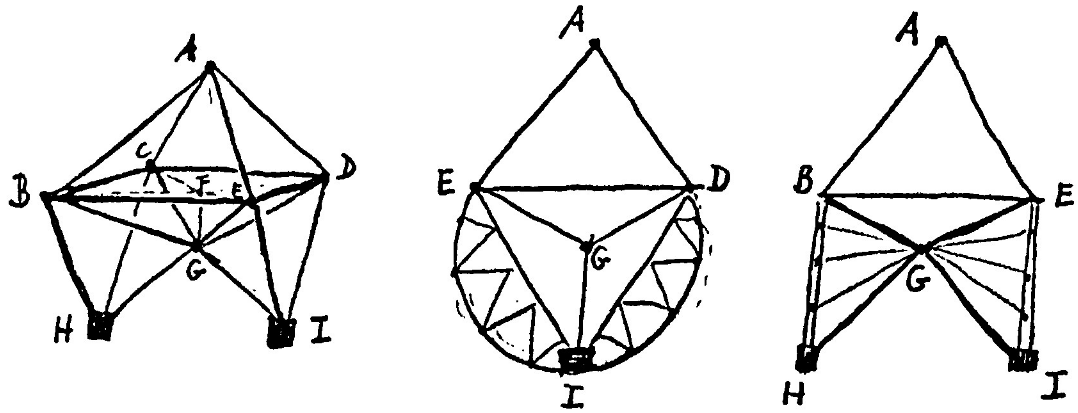
Three types are suggested. As to their steerability, two have an alt-az mount, and one has an XY mount, which easily could be changed into a polar mount if wanted. As to the movability, either the telescope is moved with its complete mount, or the lower part of the mount is fixed to the ground and is supplied at each observing station, for example in the form of concrete pillars.

type	steerability	change to polar	lower mount movable	lower mount fixed
one-point support	alt-az	no	yes	yes
yoke	alt-az	no	yes	no
cradle	XY	yes	no	yes

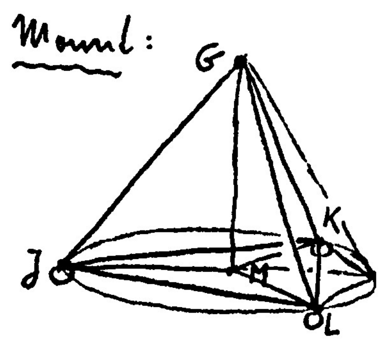
(1) One-Point Support

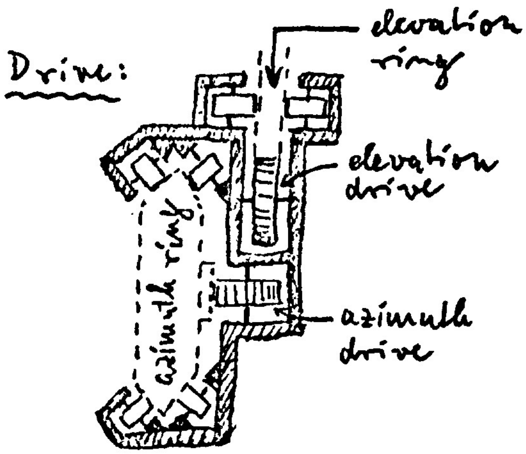
The basic structure is an octahedron with a flatter lower part. The corners of the square, BCDE, and its center, F, yield 5 points on which the reflector dish is fixed; point A holds the feed. The total weight of the telescope is held at G with a universal joint, for both azimuth and elevation rotation.

The structure is completely balanced by two counterweights at H and I. Planes BHC and EID hold one elevation ring each; both rings are braced against point G.



Point G is held on the upper corner of a tetrahedron. Its three basic points, JKL, sit on wheels, and they hold the azimuth ring which is braced against M and G. The azimuth ring carries no weight of the telescope; it carries only the forces from torques around G, resulting from asymmetries of wind loads.



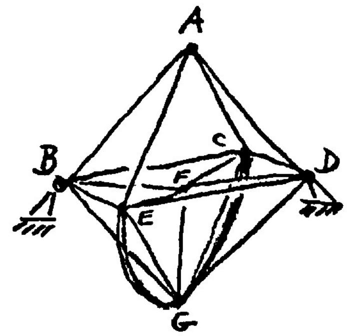


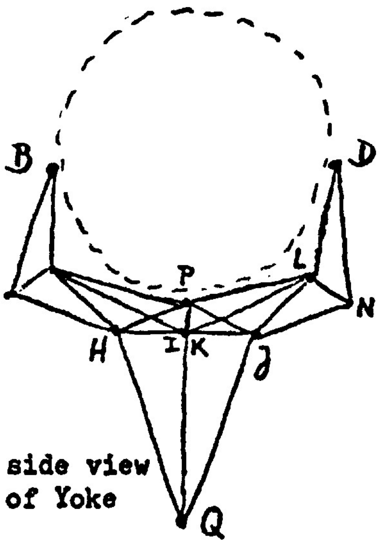
The combined azimuth and elevation drive consists of two independent identical carriages on opposite sides of the azimuth ring. The carriages travel along the azimuth ring and guide the elevation rings.

In this way, we avoid an azimuth-moving structure, as needed in other mounts.

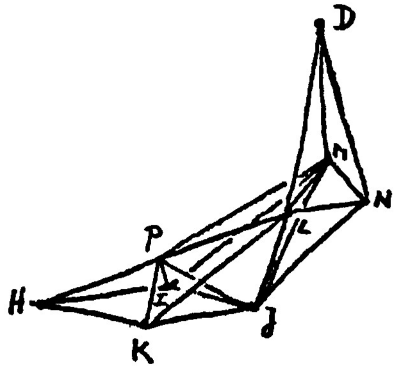
(2) Azimuth Yoke

The telescope is an octahedron, held at two corners, BD, of the basic plane; with an elevation ring fixed at the two other corners, EC.





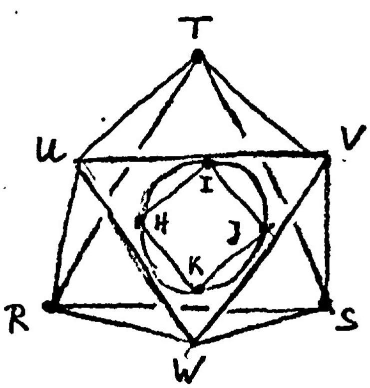
side view of Yoke



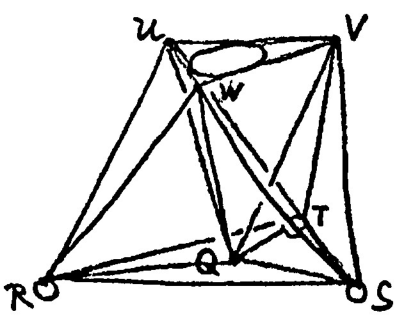
projection:

basic square of yoke, HIJK, with elevated center, P. (only one arm shown)

The yoke is held with its full weight by a pintle bearing at point Q, and sits with points HIJK in a bearing ring for the azimuth drive. The ring takes up all lateral wind forces. Points HIJK form a basic square, which, together with the lifted center at P and the pintle bearing at Q, yields an unregular octahedron. The elevation drive sits at point P.



top view



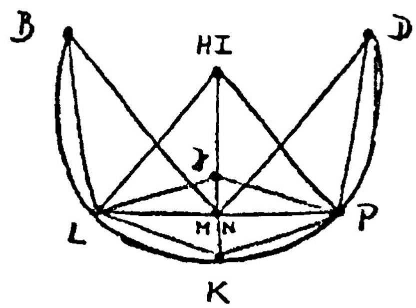
side wiew, projection

The non-rotating lower mount consists of a large lower triangle RST (all three points on wheels) with center point Q for the pintle bearing of the yoke, and a some-what smaller upper triangle UVW. The azimuth ring lies in the plane of UVW and is braced against these three points.

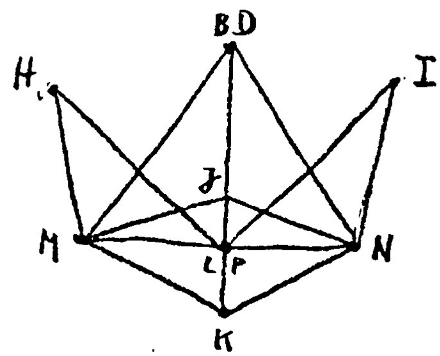
(3) Cradle

This is an XY mount which might be considered if each observing station is equipped with two concrete pillars or tripods. The telescopes (with cradles) then are moved from one station to the other by a small number of moving trucks. This cradle mount is again a universal joint, but with the telescope within it. There will be some aperture blocking for hour angles larger than 3 or 4 hours, but this would still yield at least 6 hours of unblocked tracking. There is no blocking north-south.

The telescope itself is the same as for the yoke structure: an octahedron, held at corners BD, with an east-west ring fixed at corners EC. Looking at zenith, point B should be north and point E east.

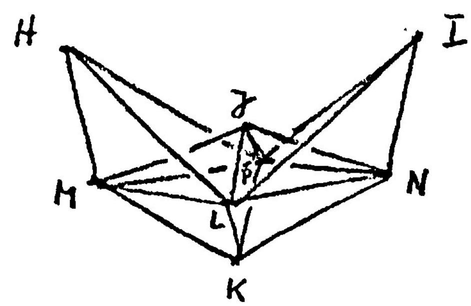


West view



North view

The bottom of the cradle is a flat octahedron. From its main plane, LMNP, four tripods start at three points each, two tripods leading to points BC where the telescope is held by two bearings, and two tripods leading to points HI where the cradle is held by two bearings.



North view, projection.
Points BC are omitted.

The drive for east-west rotation is fixed at point J, where the east-west ring of the telescope structure touches the bottom of the cradle. The north-south ring of the cradle is fixed at points BLKPD, and the north-south drive is fixed at the ground.

II. Non-Parabolic Pannels

It might be considered to make the surface pannels of a shape which is different from a paraboloid, but easier to produce and to measure. Then, for any given shape, a maximum pannel size can be calculated, such that no deviation from the true paraboloid is more than $\lambda/16$. Formulae for this condition are derived for three cases: flat pannels, spherical pannels, and toroidal pannels, but I omit the sometimes very tedious derivations of these formulae. For the focal ratio, I have assumed $f/D=1/2$, but this figure is not critical for the results.

The condition of $\lambda/16$ for the maximum deviation from the design paraboloid certainly is too conservative, since actually only the rms deviation from the best-fit paraboloid counts. This means that in the following formulae and numbers, the wavelength could always be devided by about 2.5; on the other side, a regular pattern of deviations will cause some sidelobes, thus I have omitted this factor 2.5 as kind of a safety factor against sidelobes.

1. Plane Pannels

Although plane pannels are of no direct use, I have included them for comparison. The maximum length of a pannel at the center of the dish is (D = diameter of dish)

$$\ell_{pl} = \sqrt{\frac{1}{2} D \lambda} , \qquad (1)$$

and it is only 11 % larger at the rim, which difference we neglect. For D = 26 m = 85 ft we obtain, with N = number of pannels needed:

λ	ℓ_{pl}	N_{pl}
1 cm	.36 m	4080
3 cm	.62 m	1380

(2)

These pannels are much too small, and their number is much too large, to be of any direct use. But the values for ℓ still give us a good estimate for the length over which the actual shape of a surface does not matter.

2) Spherical Pannels

Spherical pannels have the advantage that they can be easily produced and measured (for example with a pendulum of length R hanging from a tripod). The best-fitting radius R of the sphere is given by

$$R = D W^2 \qquad (3)$$

with

$$W^2 = 1 + (r/D)^2 \qquad \text{and} \qquad r^2 = x^2 + y^2 \tag{4}$$

where x and y are the coordinates (zero at apex) of the point to be fitted, which is the center of a pannel.

The maximum length of a pannel, in all directions, then is

$$\ell_{sp,c} = (8\, D^3\, \lambda)^{1/4} \qquad \text{for} \quad r = 0 \tag{5}$$

$$\ell_{sp,r} = \frac{D}{r}\,(D\,\lambda)^{1/2} \qquad \text{for} \quad r \neq 0. \tag{6}$$

For D = 26 m, we obtain, for the center and for average $r = D/2^{3/2}$:

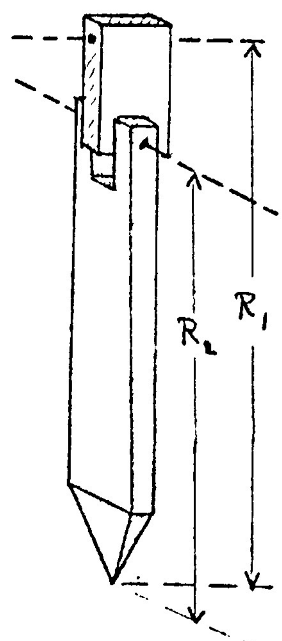
λ	$\ell_{sp,c}$	$\ell_{sp,av}$	N_{sp}
1 cm	6.10 m	1.44 m	245
3 cm	8.03 m	2.50 m	81

(7)

We see that spherical pannels can be made considerably larger than plane ones; and at least for λ=3 cm their number is acceptable.

3) Toroidal Pannels

Toroidal pannels, too, can be produced and measured with a pendulum, but the pendulum now must have an intermediate joint. In two directions, perpendicular to each other, the pendulum then has two different radii, R_1 and R_2.



The best-fit radii are given by

$$R_1 = D\,W^3 \qquad \text{and} \qquad R_2 = D\,W. \tag{8}$$

The maximum length of a pannel in radial direction is

$$\ell_{to,c} = (8\, D^3\, \lambda)^{1/4} \qquad \text{for} \quad r = 0 \tag{9}$$

$$\ell_{to,r} = \left(\frac{D}{r}\, W^5\right)^{1/3} (D^2 \lambda)^{1/3} \qquad \text{for} \quad r \neq 0. \tag{10}$$

The first term of (10) varies between 1.52 at the rim and 2.02 at r=D/8, and it is 1.60 in the average:

$$\ell_{to,r} = 1.60\ (D^2\lambda)^{1/3}, \quad \text{for average r.} \qquad (11)$$

The maximum length in perpendicular direction is

$$\ell_{to,p} = W\ (8D^3\lambda)^{1/4}. \qquad (12)$$

The limits (10), (11) and (12) would hold only if the pannels would extend in only one direction. If a pannel extends in both directions, the limits are somewhat smaller; I have calculated the case where the pannel area is maximum for given λ, and the result is:

$$\ell_{to,r} = 1.33\ (D^2\lambda)^{1/3} \qquad (13)$$

$$\ell_{to,p} = 1.36\ (D^3\lambda)^{1/4}. \qquad (14)$$

} combined, average r

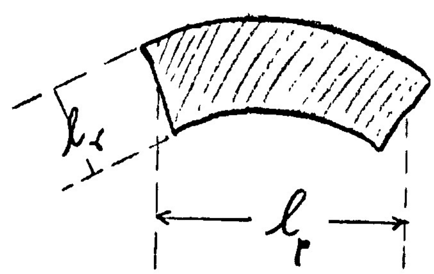
For D = 26 m, we obtain

λ	$\ell_{to,r}$	$\ell_{to,p}$	N_{to}
1 cm	2.52 m	4.95 m	44
3 cm	3.62 m	6.51 m	24

(15)

The center part, of course, is the same as for the spherical pannels, as given in (5) and (7). We see that the number of pannels in(15) is much reduced as compared to (7); even for λ=1 cm the number of pannels is acceptable.

Since $\ell_p > \ell_r$, the pannels look like sections of a ring.



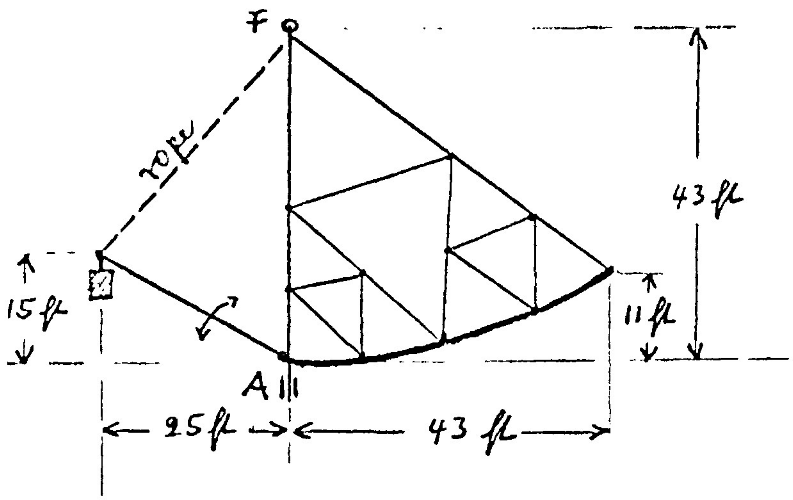
Conclusion:

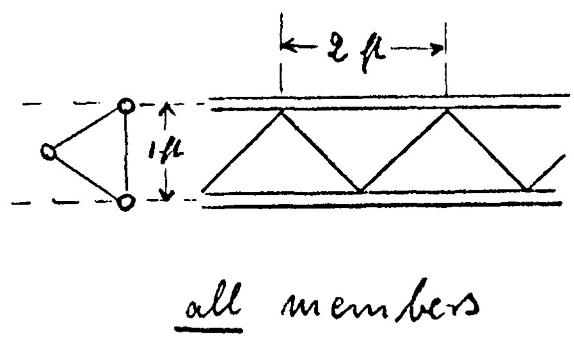
With respect to the above results, I would recommend giving the spherical (or toroidal) pannels some serious consideration, as one of the competing possibilities. For a decision, though, a comparison with other procedures would be needed.

III. Templet for Surface Adjustment

For an 85-ft dish, the gravitational limit is $\lambda_{gr} = 5$ mm. For wavelengths $\lambda \geq 1$ cm and a reasonable telescope structure, gravitational deformations play no role, and we just have to adjust the surface to a paraboloid when looking at zenith. The best way seems to be using a parabolic templet, covering half the dish and rotating in azimuth 360°. For an easy application, the feed support legs must not cut through the surface, which means the dish must be inside the four basic points of the octahedron.

The templet should have exactly the same weight as feed and receivers later on will have; the templet should hang with all its weight at the focus F and should be held at the apex A with a gliding cylinder bearing, and it should be completely balanced by a counterweight. In this way, the templet does not give any deformation to the dish.





Next, we need a weight estimate. In order to let the templet deform with temperature the same as the telescope structure, we prefer to make it from steel. To make it as light-weight as possible, I started with the lightest piece in the Steel Construction Manual, which is a pipe of 0.405 inch outer diameter, with 0.24 lb/ft. Since no external forces are applied, we might go to an l/r ratio of 200; the pipe has r=0.12 inch, which gives an unbraced length of 2 feet. Adopting the weight of the braces with 60% of the weight of the chords, we obtain 326 lb for the templet. The counterweight, then, must have 148 lb, and alltogether we have

$$\begin{aligned} \text{templet} &= 326 \text{ lb} \\ \text{counterweight} &= 148 \\ \hline \text{total weight} &= 474 \text{ lb} \end{aligned} \qquad (16)$$

which is about the right weight for replacing feed and receiver.

If for some reason a structure is desired where the feed support legs do cut through the surface, the templet still could be used. We build it in two pieces, one piece being the large outer triangle, right-hand in the drawing. We connect this triangle to the main body by rotary joints at one of the chords, and connect the other chord with clamps or springs. In this way, the outer triangle can easily be folded against the main body. The upper part of the templet, then, must be somewhat more slender than the one drawn.

The easiest way of doing the surface adjustment would be having two men working at it: one man stands on the surface and waches the distance between templet and surface, the second one is under the surface and turns the adjustment screws. The question is whether the weight of two men deforms the surface too much. If the telescope is built for observation up to 30 mph wind velocity, the wind force on the surface is up to 18,000 lb, which is the weight of about 100 men, and the weight of two men is negligible.