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The Fixed Elevation Transit Telescope

1. Concept

The idea of a transit telescope consisting of a parabolic dish mounted at a fixed elevation angle, yet capable of rotating about an azimuth axis, is not new (1,2). Its main advantage is that a very large reflector surface of high accuracy may be built since gravity deflections are constant and can be allowed for in the design and construction.

It suffers the disadvantage of all transit radio telescopes, that of giving only two (in this case) opportunities to observe any given object in a day. Only a very limited track capability is possible if the reflector is parabolic. The sky cover is also somewhat limited.

However, an obvious way to increase the tracking time for a given source is to provide limited ability to move the beam in elevation. This can be done (3) by using a spherical dish and a phase corrected feed (4,5). All the required techniques are known and developed, so that before considering the practical construction aspects in detail, let us examine the requirements for sky cover and for azimuth and elevation motion of the beam.

2. Astronomical Requirements

(a) Sky cover

Let the dish be built so that the altitude angle of the beam may be varied from h to h + s (Fig. 1). Thus h is the minimum altitude angle which can be observed, and the beam may move through an altitude scan angle s above h.

In a practical telescope the choice of h will be governed by many considerations. One of these will be the amount of atmosphere which it is permissible to look through; another will be the desire to see, from a chosen site, the most interesting objects in the sky. For simplicity, we will choose $h = 30°$ since, although it is obviously desirable to keep h small to increase sky cover, at 30° we already commit ourselves to making all observations through twice the zenith atmospheric depth.

If the telescope is at north latitude = ϕ, then no sources can be seen at declinations south of

$$\delta_s = h + \phi - 90° \qquad (1)$$

For example, at NRAO ($\phi = 38°26'$) with $h = 30°$ this declination limit is $-21°34'$.

The north declination limit δ_N is given by

$$\delta_N = 90 - \phi + h + s \qquad (2)$$

Clearly, when observing δ_s the telescope azimuth is south, and when observing δ_N it is north. As an example, at NRAO, if $h = 30°$ and $s = 8°26'$ all positive declinations can be observed.

(b) Hour angle tracking

By moving the telescope in azimuth (Z) and in altitude over the range h to h + s we can track a source as it moves in hour angle. The maximum extent of the tracking range required in LHA can be taken to be 2 hours. The following table, which is only approximate, shows the azimuth and elevation motions needed to give this hour angle range for an instrument located at NRAO with $h = 30°$.

Table 1. Ranges of azimuth and elevation motion needed to give from 1 to 2 hours track for sources at various declinations. Telescope at $\phi = 38^\circ 26'$ and $h = 30^\circ$. Table compiled from NRAO conversion tables (H.A.,Decl.) to (Alt.,Az.).

Declination of source	Azimuth and elevation at start of observation		Azimuth and elevation at end of observation		Hours source tracked	Altitude Range S
	Z	h	Z	h + s		
-20°	164°	30°	196°	30°	1 hr 52 min	1°34'
-10°	136°	30°	170°	41°	2 hrs	11°
0°	118°	30°	150°	47°	2 hrs	17°
	118°	30°	132°	40°	1 hr	10°
+10°	101°	30°	128°	51°	2 hrs	21°
	101°	30°	113°	41°	1 hr	11°
+20°	87°	30°	109°	53°	2 hrs	23°
	87°	30°	97°	41.5°	1 hr	11.5°
+30°	74°	30°	91°	54°	2 hrs	24°
	74°	30°	82°	42°	1 hr	12°
+40°	61°	30°	71°	52°	2 hrs	22°
	61°	30°	66°	41°	1 hr	11°
+50°	48°	30°	55°	48°	2 hrs	18°
	48°	30°	52°	39°	1 hr	9°
+60°	36°	30°	40°	45°	2 hrs	15°
	36°	30°	38°	37°	1 hr	7°
+70°	22°	30°	26°	41°	2 hrs	11°
	22°	30°	24°	34°	1 hr	4°
+80°	6°	30°	10°	34°	2 hrs	4°
	6°	30°	8°	32°	1 hr	2°

Table 1 shows that to get a full 2 hours track h must be about 24°. However, an h of 12° gives always at least one hour of track and more at some declinations.

(c) Drive rates

A study of Table 1 shows that the drive rates for tracking are very modest, only at most 17° per hour in azimuth and 12° per hour in elevation.

Higher slewing rates will, of course, be needed.

(d) Choice of site

It is probably generally agreed that the telescope should observe the galactic center, so that cover to $\delta = -30^\circ$ is needed. At NRAO this represents rather a low value for h (21°34'). It may be desirable to keep h about 30° and consider a lower latitude site; Texas, Florida, or Hawaii are all attractive.

3. Structural Suggestions

The reflector should be of the shape sketched in Fig. 2. The width W and the length L are simply related to the choice of h and of the feed. The feed illuminates with correct phase and a suitable amplitude taper a circle of diameter W. If W and L are measured along the curved reflector surfaces

$$L = Rh + W \tag{3}$$

where R is the radius of curvature of the spherical surface and h is now measured in radians. Table 2 shows some choices of L R h and W as examples.

Table 2. Some possible sizes for the reflector. The approximate height of the structure $H \doteqdot \cdot 866\ L$ (for $h = 30^\circ$) is also given.

W	R	h	L	H	Remarks
1000 ft.	1000 ft.	11.4°	1200 ft.	1040 ft.	R-W relation
1000 ft.	1000 ft.	22.8°	1400 ft.	1220 ft.	Similar to Arecibo
1000 ft.	1500 ft.	11.4°	1300 ft.	1130 ft.	Rather tall
1000 ft.	1500 ft.	22.8°	1600 ft.	1400 ft.	Taller
600 ft.	600 ft.	11.4°	720 ft.	620 ft.	
600 ft.	600 ft.	22.8°	840 ft.	730 ft.	

The general form of the structure should be to get the loads to the horizontal bearing surface as directly as possible. Fig. 1 suggests the feed might be carried on a vertical feed tower, not by structure connected to the dish. The aim should be to remove as many as possible of the variable loads from the dish support structure. Various structural questions come to mind. Is not a lot of the dish support structure mainly in compression? Is concrete a possible structural material? If so, how is the bearing done? Is this a place for a high vicosity hydrostatic bearing system? Or floatation again?

4. The Feed

Problems of feeds for spherical dishes still exist, but very considerable work has been done for Arecibo and more is planned. Although the line feed still looks best for Arecibo, the shaped reflector feed should still be considered, despite the illumination and aperture blocking difficulties (6). A few questions arise here. Would it be worth considering a parabolic/spherical shape for the main reflector? A line feed would not make sense for such a shape, but in fact phase correction and steering is only needed in elevation, and in the other plane the reflector shape might be parabolic.

5. Brief Summary

This is a possible telescope within our present structural and electronic capabilities. It is not in the least esoteric and might be cheap. Heavy steel could easily go in for 50 cents a pound erected. Precise work would only be needed at the surface, the bearings, and the feed.

The working group will look over the general concept, but, unless obvious difficulties emerge, it is worth some effort.

6. Question

The big question is whether the sky cover and tracking abilities are good enough to satisfy astronomers. We would welcome comments particularly on this point.

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March 4, 1965

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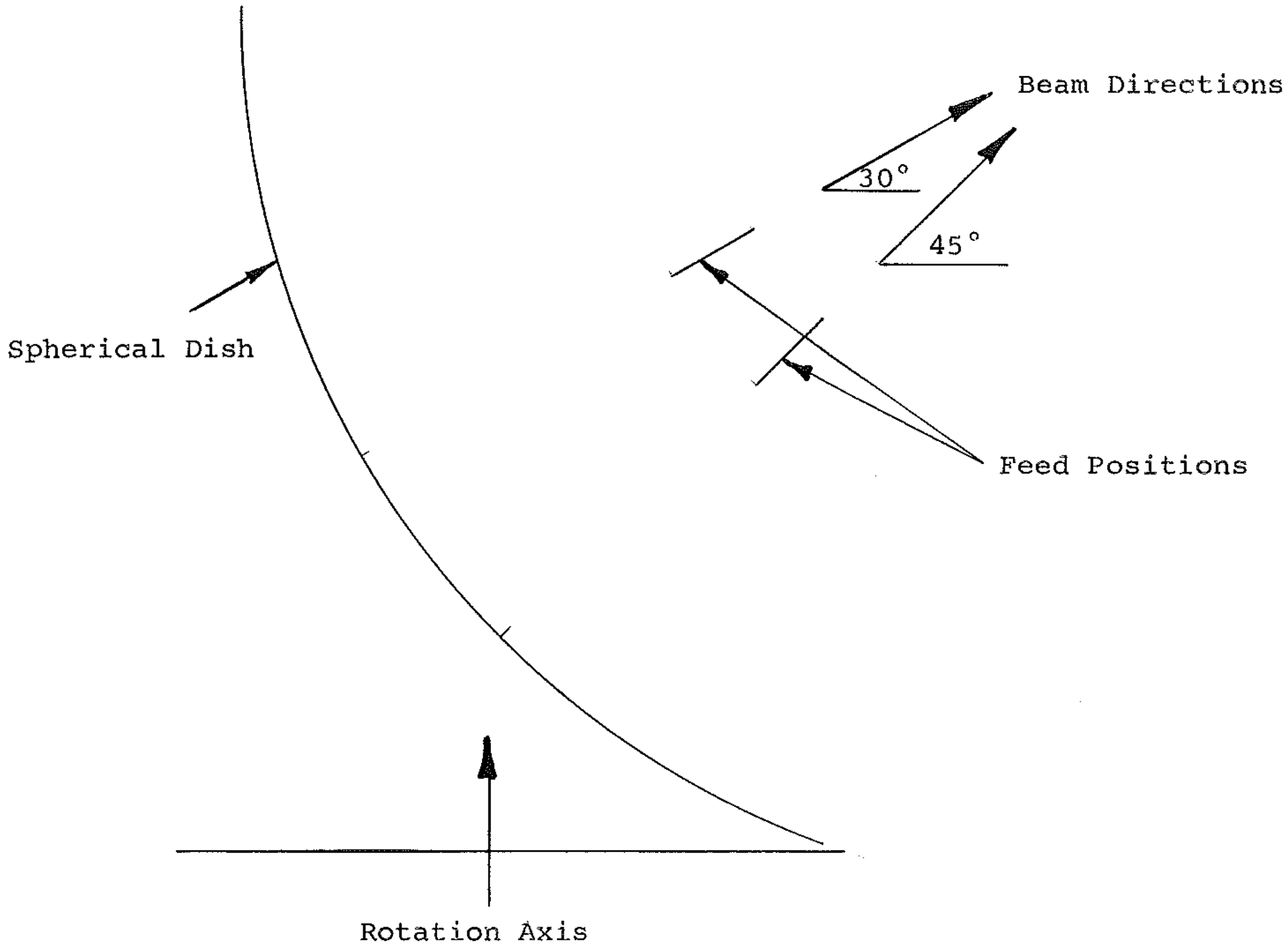

Figure 1

The fixed elevation transit telescope, showing feed positions for an elevation angle (h) of 30° and a scan angle (s) of 15°.

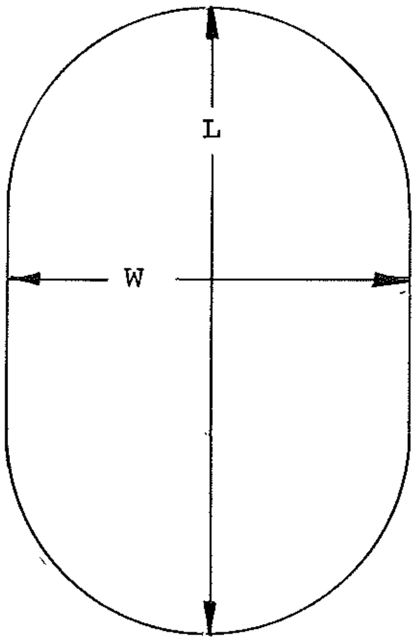

Figure 2

The suggested outline shape of the dish.