The Gravitational Deformation of the Ceduna-1 Antenna

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1 Summary

This note is the third in a series that investigated the Ceduna-1 antenna, with particular emphasis on its ability to support 22GHz observations. All antennas deform as they are tipped from the zenith to the horizon; the important issue is whether the deformations are such that the gain of the antenna changes significantly with elevation. Our evidence indicates that the Ceduna-1 antenna performs well in this sense; furthermore, the movement of the subreflector with respect to the focus of the best-fitting paraboloid is modest, so that there is little need to provide either axial or lateral focus adjustments.

2 Introduction

In all these experiments we set up a coordinate frame locked to the central hub. We looked for the 3-D movement of the reflecting surfaces relative to this frame as the antenna tipped in elevation. Two techniques were used:

- "theodolite mode", with a telescope rigidly attached to the hub, tracking a target fixed to the surface. This measured the movement normal to the line of sight. These experiments are described in detail in AT/39.3/067 (Kesteven & Parsons, June, 1997).

- "tape measure mode", with a fine steel wire at constant tension between the hub and a target. This measured changes in the radial distance. This work was carried out in June 1998, and is described in section 3.

Section 4 brings together the results from the two experiments.

3 Radial Distance Measurements

The basic scheme is shown in figure 1. The wire is fastened to the subreflector rim; it drops to a pulley attached to the hub; the wire crosses to a second pulley which allows a weight to provide a constant tension at all elevations. A flag attached to the wire in the region between the two pulleys allows us to monitor the changes in distance.

The geometry of the arrangement is important: as shown in figure 1, for example, the experiment is most sensitive to axial movement, and quite insensitive to lateral displacement. We repeated these experiments with the wire brought directly to the hub centre, so thata component of the lateral

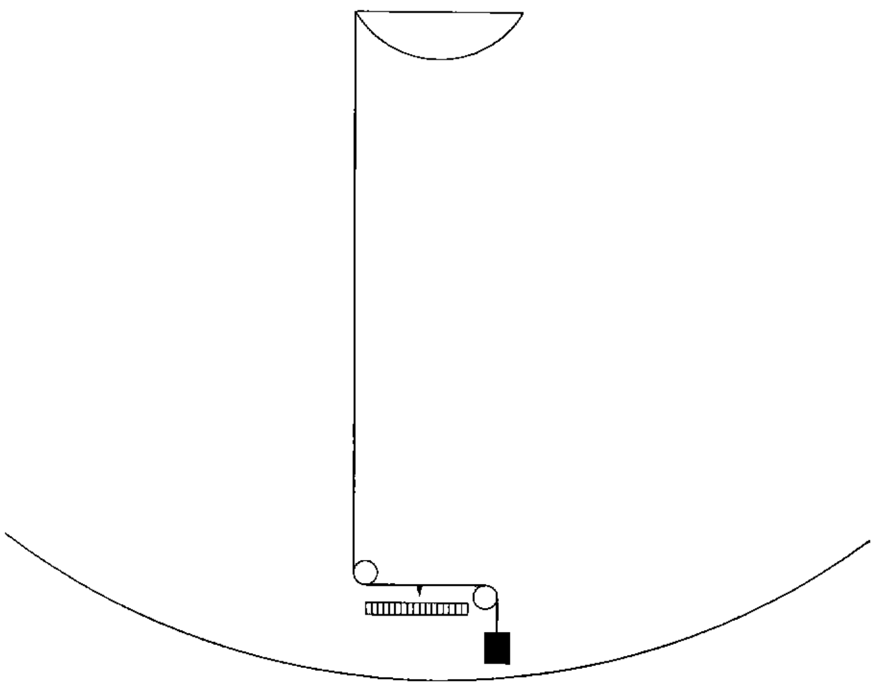

Figure 1: Layout for the taut-wire experiment

movement could be measured. Thus, by varying the geometry we could provide some overlap with the "theodolite mode" experiments.

We use the following convention to describe locations in the hub's coordinate frame: suppose the antenna to be pointing to the horizon, and you are looking into the reflector; North is at the top, and East is to the right.

The configurations used in these experiments were :

1. Wires were attached to the East and West edges of the subreflector, then brought down vertically. The (East/West) mean measured the subreflector axial movement; the difference measures the subreflector rotation about the N-S axis. (No rotation was observed).

2. Wires were attached to the N and S edges of the subreflector, and dropped vertically. The (N/S) mean measured the subreflector axial movement; the difference measured the rotation about the E-W axis.

3. Wires were attached to the N and S edges, and dropped directly to the centre of the hub. The mean gives the axial movement, as before. But the difference now includes a component of the subreflector lateral movement.

4. A wire was attached to the N edge of the main reflector. This was in preparation for the next arragnement, and confirmed that the main reflector rim moved almost entirely normal to the line from the hub to the rim.

5. A wire was attached to the N edge of the subreflector, then to a pulley on the N edge of the main reflector, and finally to the hub. This measures (in conjunction with the previous arrangement) the movement between the subreflector (translation and rotation) relative to the main reflector. The point here was to provide a confirming tie-in to the earlier "theodolite mode" experiments.

6. This experiment was repeated using the S edges of the subreflector and main reflector.

4 Results

There is some overlap between the theodolite and the tape experiments - in the lateral subreflector motion, as well as the movement between the subreflector and the main reflector. The results are in good agreement,

The results are summarised in Tables 1 and 2.

Table 1: Subreflector Movement with respect to the Hub

elevation (deg)	axial (mm)	lateral (mm)	rotation (arcmin)
90	0.00	0.0	0.0
75	0.26	-4.2	2.9
60	0.28	-7.8	6.4
45	0.25	-11.4	7.4
30	-0.14	-13.9	9.3
15	-0.72	-15.4	10.3
3	-1.24	-16.6	10.3

Notes:

- positive axial movement means the subreflector moves towards the vertex.

- positive lateral movement is towards the north.

- postive rotation has the N end dropping towards the reflector.

The main reflector movement in Table 2 is from the June, 1997 study.

Table 2: Main Reflector movement

elevation (deg)	axial focus shift (mm)	rotation (arcmin)
90	0.0	0.0
75	-0.5	-1.1
60	-1.3	-2.1
45	-2.4	-3.0
30	-4.4	-3.5
15	-6.2	-3.9
1	-8.2	-4.0

5 Discussion

5.1 axial focus error

The deformation of the antenna shortens the focal length as the antenna tips from the zenith to the horizon; the subreflector moves outwards, with a total displacement (reflector plus subreflector) of 9.4mm. The defocussing damage could be minimised by biassing the subreflector by 4.7mm.

5.2 lateral focus error

The rotation of the best-fit paraboloid (as the antenna tips from the zenith to the horizon) is 4.0 arcmin, corresponding to a shift of 11mm at the focus. The subreflector moves 17mm in the same direction. An N bias of 8mm would minimise the error. We note that the subreflector is currently offset by 13mm (towards the north) from the optical axis (measured at the zenith).

5.3 pointing

Our data are all referenced to the hub. If the elevation encoders are rigidly attached to the hub, then the pointing model will contain an elevation-dependent term based on the rotation of the best-fit paraboloid as well as the lateral subreflector offset; the term will be reduced if the hub has a rotation component not shared by the encoders. Radio pointing data alone can resolve this matter. The magnitude of the term is around 2 arcmin.

6 Conclusion and Recommendations

- The Ceduna-1 antenna shows only modest deformation as it tips from the zenith to the horizon. The focus errors can be kept below 5mm by a small bias in the positioning of the subreflector ... 8mm laterally (to the North), and 4mm axially (towards the vertex).

- The surface rms will increase as the antenna tips, with a corresponding drop in gain (of order 20% at the extremes). However, the present data are not considered good enough to warrant a bias-setting of the antenna. Holography studies at mid-elevations should clarify this matter.