Notes on Possible Sensors for Improving the Pointing of MMA Antennas

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Introduction

This note is concerned with sensors that may be of use in sensing the various deformations in the MMA antennas that result in pointing changes. There are a variety of sensors that may be useful and we have experience with many of these. Our experience is confined to sensors using propagation of a light beam through a turbulent atmosphere and it is the turbulence that invariably imposes the limitation on the accuracy of measurement. We have many experimental results, albeit at greater ranges than would be required for the MMA antennas, but the strong suggestion is that the application of various simple sensors may improve the MMA antenna pointing.

Sensors are available to use light beams to measure:

1) Tilt
2) Displacement perpendicular to a light beam
3) Displacement along a light beam (range)

TILT

NRAO has a lot of experience measuring the tilt of a mirror remotely situated from the measuring instrument. The instrument used is an "autocollimator." A light beam is transmitted to a remote mirror and the instrument uses the returned beam to measure the tilt of the mirror. The instrument typically outputs two analog voltages that represent the tilt of the mirror in two orthogonal planes. A data sheet for a commercially-available autocollimator is shown in Figure 1.

Many years ago NRAO investigated the possibility of establishing a stable platform at the intersection of the AZ and EL axes of a large radio telescope [1]. Tests were conducted in Green Bank to measure the angular fluctuations over a slant path of around 50m with the results shown in Figure 2, along with the proposed configuration. The fluctuations were measured in a bandwidth of several Hz and may be seen to be less than 0.5 arcseconds.

A similar idea was worked on for the GBT and tests in Green Bank were made through a heated tube over a 60m distance. The results are shown in Figure 3 and are quite low. These measurements were made with a Rank Taylor Hobson instrument that is "overkill" in terms of range for any MMA application. Several companies make instruments for shorter ranges with sub-arcsecond accuracies.

DISPLACEMENT

A useful method of measuring displacement in two orthogonal directions perpendicular to the measurement beam is to use a quadrant detector. This device provides two electrical signals that are a measure of the position of the centroid of a light beam on the detector. Such a system is very useful for measuring X-Y shifts in the subreflector, for example. A quadrant detector is used in this way on the 12 Meter Telescope and over a 6m path turbulence results in a beam wonder of less than 10 microns with a bandwidth of around 1 Hz. Further work at NRAO has been aimed at the GBT; details are given in [2] and [3]. All the measurements suggest that at a range of a few (up to ten) meters, accuracies on the order of 10 microns over many minutes are realizable. It would be a simple matter to set up a test to more or less exactly simulate any conditions that may be defined for use on the MMA antennas. We have a system available in Green Bank for testing.

RANGE

NRAO has a lot of experience with laser rangefinders [4] and is now developing a simplified version of the GBT rangefinder for JPL in order to measure the range to the wingtip antennas from the fuselage on an aircraft equipped with a radar interferometer. We expect a precision (with several caveats) of around 20 microns for the differential distance between the wingtips.

SUMMARY

- Remote sensing to a target 10m away
- Time scales uncertain but longer than several minutes
  - TILT
    - Autocollimator plus remote mirror
    - Accuracy around 0.2 arcseconds
    - Cost $5-10k
  - DISPLACEMENT
    - Laser plus quadrant detector
    - Accuracy around 10 microns
    - Cost $3k
  - RANGE
    - Amplitude modulated laser
    - Accuracy 20 microns
    - Cost $7k

NOTE: Above costs do not include labor - just components.

TENTATIVE CONCLUSIONS

Any of the above may be used to improve the pointing of the MMA antenna. One possibility would be to use a high accuracy incremental encoder (Heidenhain ROD 905, for example, with a quoted accuracy of ± 0.2 arcsecs) with instrumentation described here to remove the relevant thermal and wind deformations. The point should be made that all the atmospheric results were obtained in Green Bank and that the high altitude site may be quite different and perhaps some simple tests at the site should be considered.

REFERENCES

[1] *A 65-m Telescope for Millimeter Wavelengths*. Findlay and von Hoerner. 1972. Library of Congress Catalog Card Number 72-90554.

[2] GBT Memo #144, "Monitoring the Movement of the GBT Arm," J. M. Payne December 1995.

[3] GBT Memo #149, "First Tests of a Quadrant Detector," J. M. Payne and Dwayne Schiebel. March 1996.

[4] "Rangefinder with Fast Multiple Range Capability," J. M. Payne,

D. Parker and R. F. Bradley, *Rev. Sci. Instrum.*, 63(6), June 1992.

SPECIFICATIONS ON TAYLOR-HOBSON AUTOCOLLIMATOR

TYPE: DA80

MEASURING RANGE: ± 80 arcseconds

ACCURACY (over full range): ± 0.8 arcseconds

ACCURACY (over any 20 arcsec. sub-range): ± 0.2 arcseconds

MAXIMUM WORKING DISTANCE: 25 mm

Figure 1

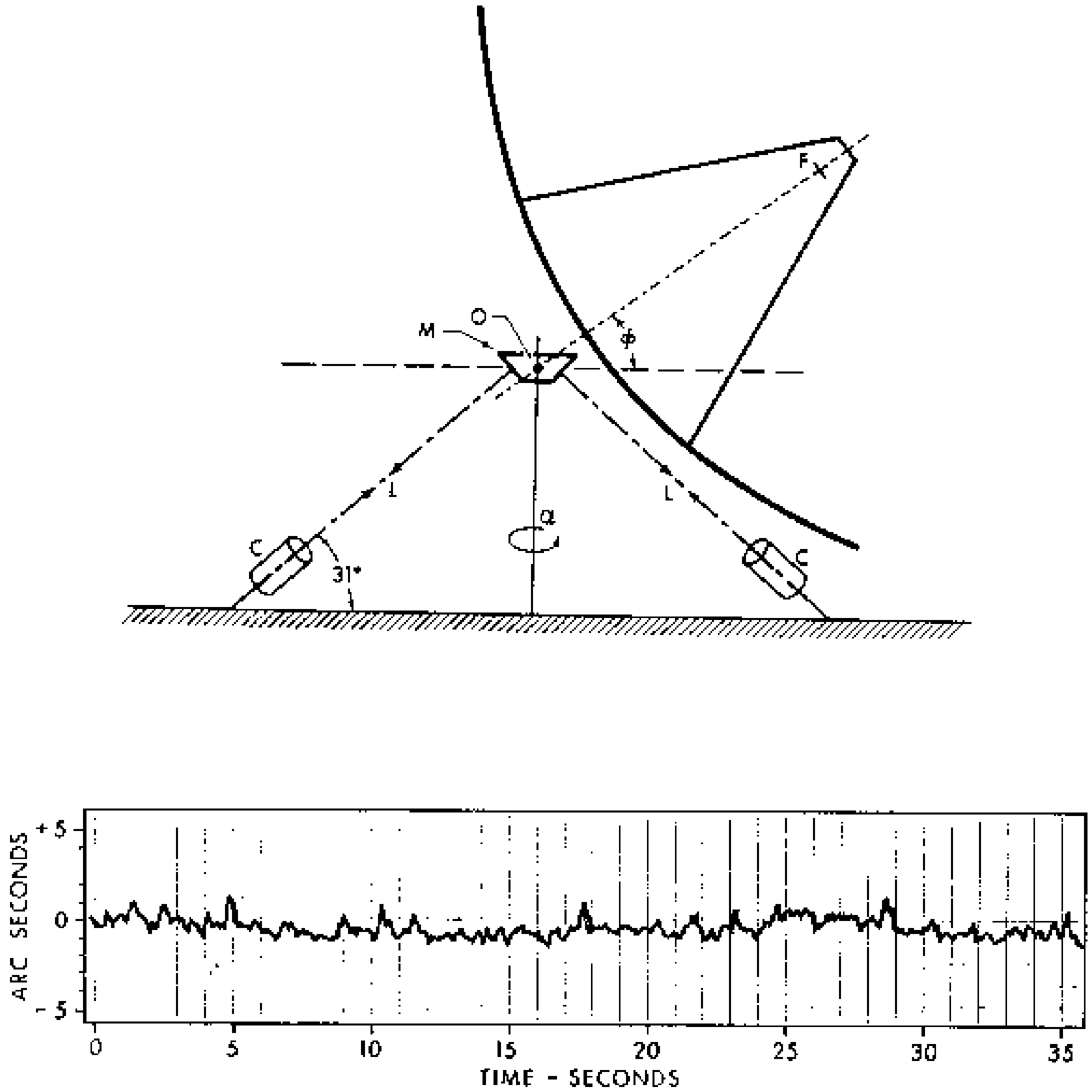

Figure 2

BANDWIDTH (milli Hz)	RMS (arcseconds)
0.00 - 0.01	0.08
0.01 - 0.10	0.23
0.10 - 1.00	0.12
1.00 - 10.0	0.06
0.0 - 1000.0	0.5

Figure 3