

WY/GR BK

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NOTES ON POSSIBLE SENSORS FOR IMPROVING THE POINTING OF MMA ANTENNAS

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INTRODUCTION

Peter Napier has asked me to quickly put together some notes on 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 wander 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  $\pm 0.2$  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.

## Type DA80 (Code 142/63)

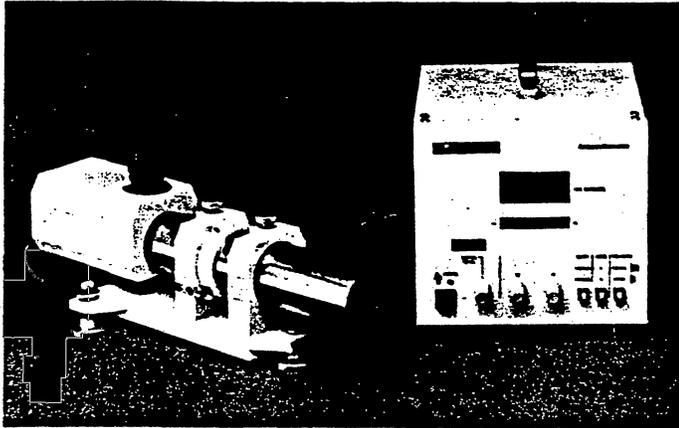
Measuring range: 160 seconds of arc ( $\pm 80$  secs)

Accuracy  
(over total range):  $\pm 0.8$  second  
(over any 20 sec  
sub range):  $\pm 0.2$  second

Direct reading to: 0.1 second

Max. working distance

for full range: 25m (80 ft)  
for  $\pm 40$  sec: 50m (160 ft)  
for  $\pm 20$  sec: 100m (320 ft)



DA80 Dual-axis Autocollimator.

## Type DA 200 (Code 142/65)

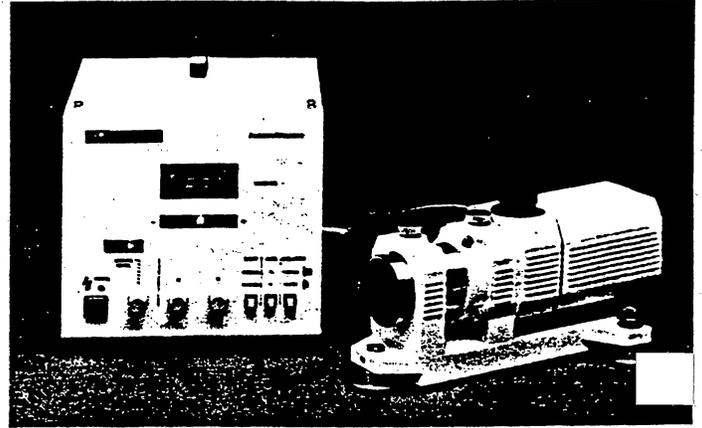
Measuring range: 400 seconds of arc ( $\pm 200$  secs)

Accuracy  
(over total range):  $\pm 2.0$  seconds  
(over any 60 sec  
sub range):  $\pm 0.5$  second

Direct reading to: 0.1 second

Max. working distance

for full range: 5m (15 ft)  
for  $\pm 100$  sec: 10m (30 ft)  
for  $\pm 50$  sec: 20m (60 ft)



DA200 Dual-axis Autocollimator.

These remarkably versatile Auto-collimators utilise the latest light source and detector technology to provide dual axis operation with digital display. The high accuracy DA 80 Autocollimator has a laser diode light source to generate the collimated beam and an eyepiece system with a  $2^\circ$  field of view, while the wide angle DA 200 incorporates an infra-red light source for the collimated beam and has an eyepiece system with a  $5^\circ$  field of view.

Each Autocollimator has a large exit pupil and an LED light source independent of the main beam to assist initial setting up procedures.

Instrument control is via an electronic unit, the facia of which incorporates an illuminated analogue indication of angular displacement readable from several metres and which also indicates the direction of out of range signals. There is also a signal strength display.

Measured values of angular displacement are displayed in digital form, and the operator is offered an option to switch axis polarity between + or - to meet different applications. An adjustable zero facility allows approximately  $\pm 30$  seconds of shift in either axis.

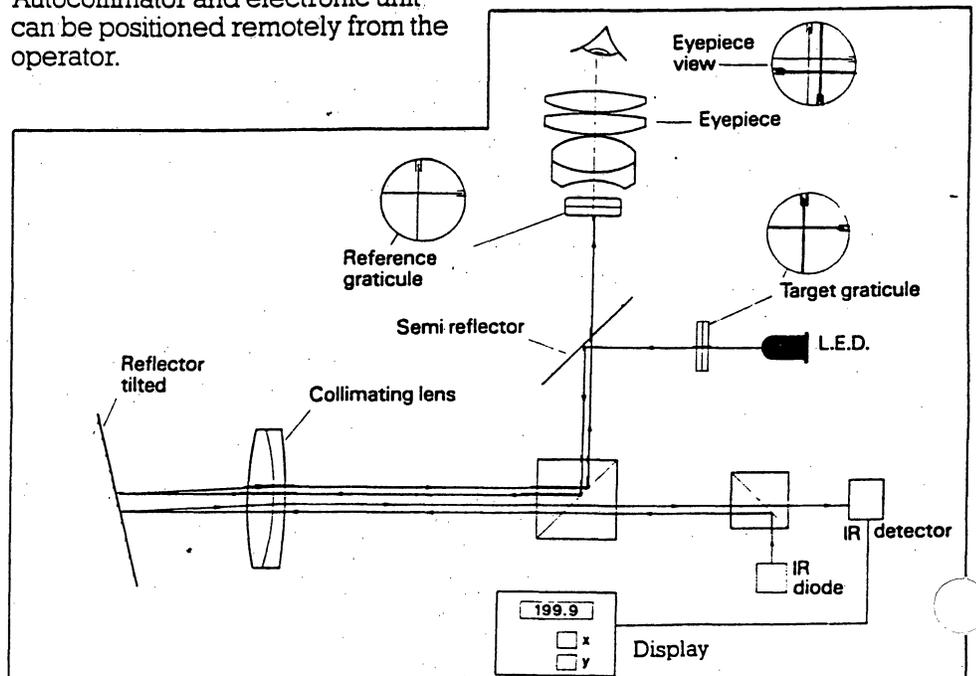
### Computer interfaces

Interfaces in RS232 form are provided for connection to various types of accessory computer, and in BCD form for connection to an HP 80 series computer.

Among many other applications, this allows computer processing of straightness, flatness and angle measurement. A remote print switch and lead is available so that the Autocollimator and electronic unit can be positioned remotely from the operator.

### Versatility

Dual axis Autocollimators are ideal instruments for workshop applications such as setting the angles of machine tool heads, checking the straightness of machine tool slideways and checking the flatness of bed plates and surface tables. Application of these autocollimators in laboratory or measuring room environments can, for example, include the calibration of polygons.



Schematic diagram of dual-axis Photoelectric Autocollimator.

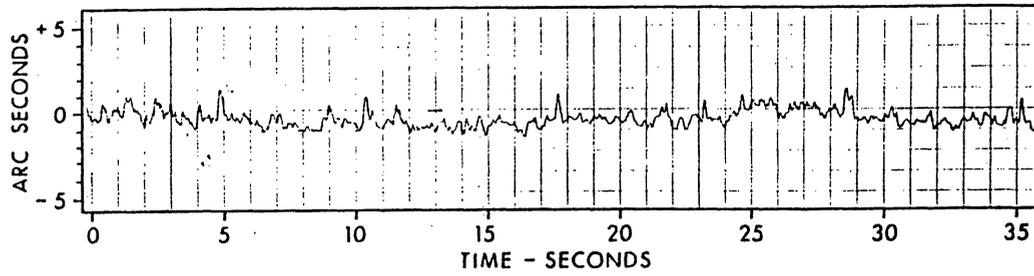
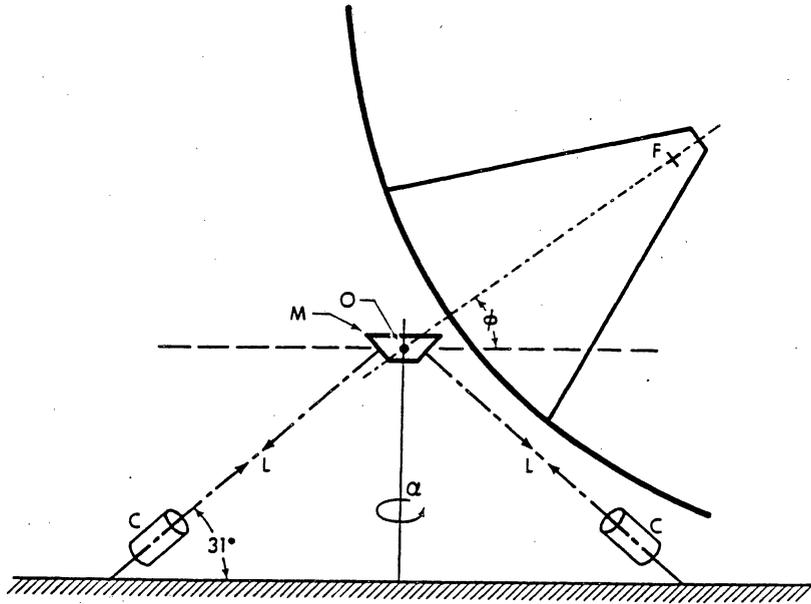


Figure 2

**GREEN BANK TESTS**  
**(THROUGH 60-M HEATED TUBE)**

<b>BANDWIDTH (milli Hz)</b>	<b>RMS (arcseconds)</b>
<b>0.00 - 0.01</b>	<b>0.08</b>
<b>0.01 - 0.10</b>	<b>0.23</b>
<b>0.10 - 1.00</b>	<b>0.12</b>
<b>1.00 - 10.00</b>	<b>0.06</b>
<b>0 - 1000</b>	<b>0.5</b>

Figure 3