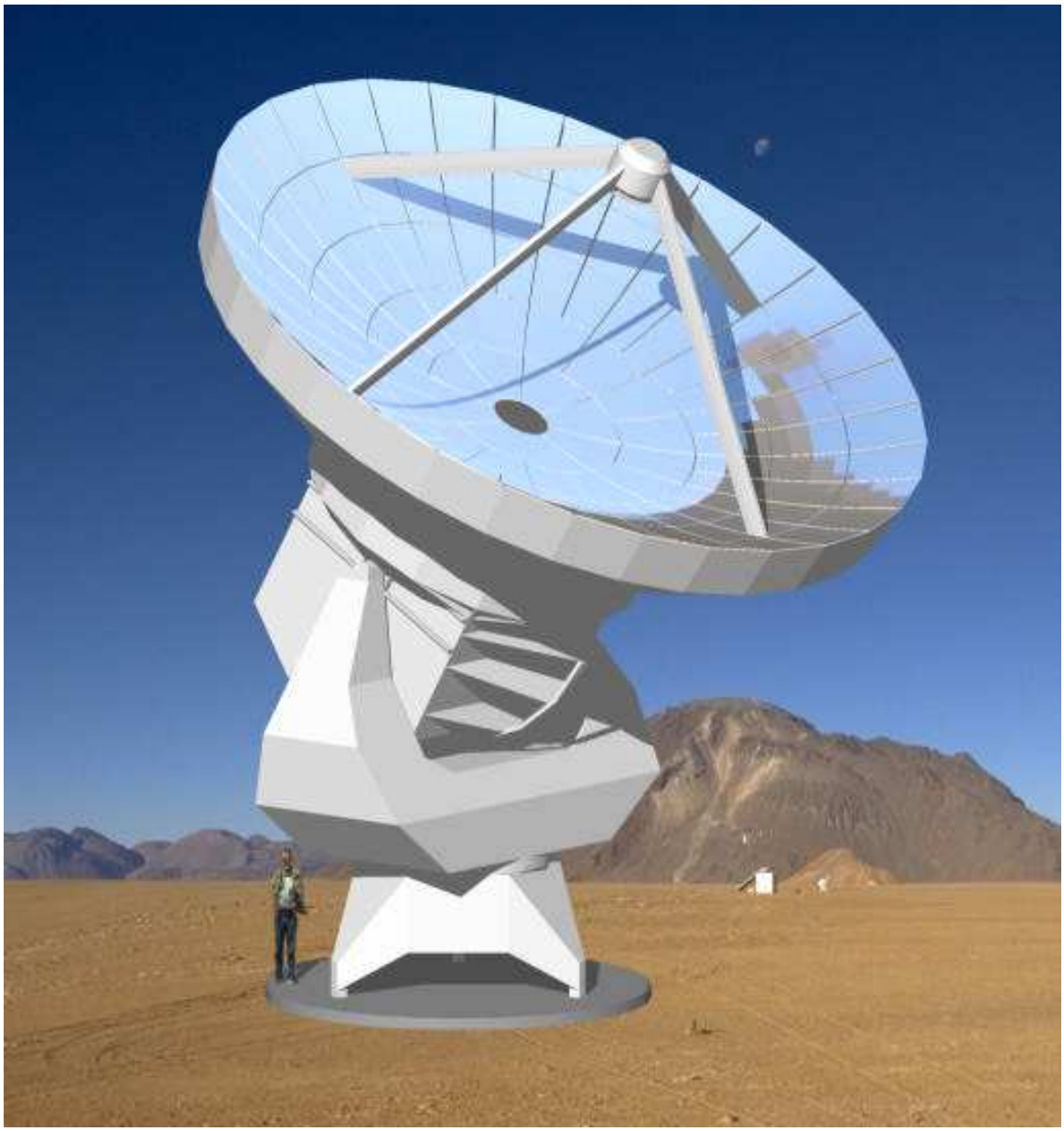
MMA Memo 240

A 10-m Antenna Design for the Millimeter Array



J. Lugten[1], J. Kingsley[1], J. Cheng[1], V. Gasho[1], and M. Fleming[2]

[1]National Radio Astronomy Observatory
[2]Berkeley Illinois Maryland Association

FEBRUARY 1999

NATIONAL RADIO ASTRONOMY OBSERVATORY
A facility of the National Science Foundation operated under
cooperative agreement by Associated Universities, Inc.

NATIONAL RADIO ASTRONOMY OBSERVATORY
949 North Cherry Avenue
Campus Building 65
Tucson, Arizona 85721-0655

John B. Lugten	N.R.A.O.	jlugten@nrao.edu
Jeffrey S. Kingsley	N.R.A.O.	jkingsle@nrao.edu
Jingquan Cheng	N.R.A.O.	jcheng@nrao.edu
Victor L. Gasho	N.R.A.O.	vgasho@nrao.edu
Matt Fleming	B.I.M.A.	mfleming@astron.berkeley.edu

Cover:Artist's conception of this antenna design on the Chajnantor, Chile site.

Photograph by Simon Radford.
Rendering by Victor Gasho.

ABSTRACT

A design is presented for a 10-m diameter millimeter and sub-millimeter wavelength radio telescope which is suitable for the Millimeter Array project. The telescope features very high accuracy, light weight, cast aluminum primary mirror panels that are machined only on their front surfaces and are supported by an all carbon fiber reinforced plastic (CFRP) supporting structure. The aluminum secondary mirror is supported by a high modulus CFRP quadripod. The equivalent surface accuracy is less than 17 micrometers RMS including effects of gravity, wind loading, and thermal effects. A large cabin is available for receivers and other antenna systems. The mount is an elevation-over - azimuth design constructed from welded steel plate. The mount uses novel techniques to measure the dish orientation; a non-load bearing reference structure, in combination with displacement sensors and tiltmeters measures the deflection of the major mount and foundation elements due to wind and thermal loading of the structure. Sub-arcsecond pointing accuracy is expected for most observing conditions at the proposed Millimeter Array site. The antenna is driven by extremely stiff, zero-backlash friction drives with a single speed reduction. Special care is taken to assure that the azimuth bearing remains flat in order to minimize a common antenna problem which is that the azimuth axis tilts with changes in azimuth angle. The base of the antenna interfaces to the foundation at only 3 points to provide kinematic support of the antenna. The 3-point support allows very rapid relocation of an antenna to a different foundation; adjustable interfaces are provided on all foundations and antennas to allow everything to be pre-leveled. A transporter design is presented which has a wide track for stability yet is highly maneuverable as required for rapid antenna access in the most compact array configuration.

This design can be improved by further optimization, mainly in the yoke and cabin. Higher resonant frequencies, improved pointing accuracy near zenith, and smaller surface error due to gravitational load are expected. Some possible approaches to scaling the design to a 12-meter aperture are discussed.

TABLE OF CONTENTS

1. Introduction.....1

2. Specifications.....2

3. Antenna Design.....3

3.1 Optical Design.....3
3.1.1 Optical Configuration 3
3.1.2 Low Noise.....3
3.1.3 Close Packing.....5
3.1.4 Solar Observing 5
3.2 Mechanical Design.....5
3.2.1 Primary Mirror Backup Structure 7
3.2.2 Panels.....9
3.2.3 Apex Structur 11
3.2.4 Receiver Cabin.....11
3.2.5 Yoke.....12
3.2.6 Base.....13
3.2.7 Bearings 14
3.2.8 Drives.....15
3.2.9 Cable Wrap.....16
3.2.10 Thermal Control.....17
3.3 Foundation 17
3.4 Control System.....19

4. Antenna Metrology.....21

4.1 Independent Reference Arms.....21
4.2 Tiltmeters.....22
4.3 Optical Pointing Telescope.....23
4.4 Temperature Probes.....23

5. Antenna Performance.....25

5.1 Surface Error Budget.....26

5.2 Optomechanical Performance....27

5.2.1 FEA Model Description and Structural Analysis....27
5.2.2 Gravity Load....28
5.2.3 Wind Load....30
5.2.4 Thermal Load....33
5.2.5 Path Length Errors....35
5.2.6 Modal Analysis....35
5.2.7 Dynamic Performance....37

6. Antenna Handling....39

6.1 Transporter....40
6.2 Receiver Service Vehicle....41
6.3 Assembly and Maintenance 42

7. Conclusion....45

8. Appendix A: Antenna Drawings....47

9. Appendix B: Locked Rotor Resonance Frequencies....59

10. Appendix C: Control System Outline....61

11. Acknowledgments....63

12. References....65