J. Webber

Report From the BIMA-NRAO-OVRO Meeting on MMA Development
3 May, 1997

R. Crutcher (BIMA)
A. Harris (BIMA)
R. Plambeck (BIMA)
J. Welch (BIMA)

D. Emerson (NRAO)
P. Napier (NRAO)
J. Webber (NRAO)

J. Lamb (OVRO)
S. Scott (OVRO)
D. Woody (OVRO)

The meeting was held at OVRO on 3 May, 1997 with the above listed attendees. On the day before the meeting the NRAO visitors were taken tothe potential Combined University Millimeter Array (CUMA) site on Upper Harkless Flats and on the afternoon after the meeting R. Crutcher and A. Harris made the same trip. The purpose of the meeting was to generate some recommendations for the MDC Executive Committee concerning the way in which BIMA, NRAO and OVRO will work together to develop the MMA, including interaction mechanisms and suggestions for MMA development projects which could be carried out at BIMA and OVRO. The overhead transparencies shown by all speakers at the meeting are shown below as attachments to this report. The agenda for the meeting is Attachment 1.

1. NRAO Plans for Development and Construction of the MMA.

As background information P. Napier described some of the top-level issues which must be considered when planning the development and construction of the MMA. His list of these issues is included as Attachment 2. The current proposal for the top-level NRAO management organization is shown as Attachment 3. A draft of a top-level strawman schedule for the Development and Construction of the MMA is shown as Attachment 4. It was emphasized that this schedule is very preliminary and is very optimistic about how quickly major tasks can be completed. However, it is desirable to have a schedule such as this if the overall funding profile for the project is to be achieved.

2. BIMA/OVRO Plans for CUMA

S. Scott described the status of site work for CUMA. His plans for current and future site work are shown as Attachment 5. An example array layout for CUMA on Upper Harkless flats is shown as Attachment 6. There was some discussion of the appropriate year in which to schedule the delivery of the two MMA antennas which will be added to CUMA. These two antennas can

be added to the MMA production line whenever a funding source is found and this is arbitrarily shown as the year 2003 in Attachment 4b. If they are needed on the CUMA site earlier than this they could be included in the first year of the antenna production run in which case they could be available as early as the beginning of 2002.It was noted that it might be possible to use an identical antenna transporter design for CUMA and MMA. D. Woody presented a list of projects (Attachment 7) that OVRO is interested in working on that are of potential interest for both the MMA and CUMA. Further details of these projects were described by J. Lamb (quasi-optical, dual polarization, sideband separation mixer -Attachment 8), D. Woody (wideband correlator - Attachment 9) and S.Scott (array control software and calibration and data management software - Attachment 10). Similarly, J. Welch presented a list of projects of interest to BIMA(Attachment 11). D. Crutcher provided more details of those items on the BIMA list which might be carried out at U. Illinois (Attachment 12) and A. Harris provided a similar list for U. Maryland (Attachment 13).

3. Mechanisms for Organizing BIMA/NRAO/OVRO Interactions

It is expected that the MDC will function at three levels in the MMA Development Project: management, advisory and engineering. The MDC will provide management for the Project through the MDC Executive Committee (shown as the MDC Steering Committee on Attachment3). There was no discussion of the functioning of this committee except to note that, in the event that there are problems or differences of opinion in the Working Groups or with the Development Projects, such problems can be quickly handed to the MDC Executive Committee for resolution.The mechanism for achieving the advisory function of the MDC will be the MMA Working Groups in which BIMA and OVRO members will provide technical advice and assistance in technical decision making. The following points came out of a discussion of the functioning of the Working Groups. Since the Working Groups will soon become critical in getting important technical decisions made in a timely way, NRAO prefers in future to have the Heads of the Working Groups be the NRAO Division Heads who have the responsibility for keeping the project on schedule. There was general acceptance of this idea. On the question of payment for the time of the members, it seems reasonable that NRAO should pay the Universities for the time of their people, although this may not be so necessary if NRAO is funding significant development projects at OVRO and BIMA. A few key non-MDC people should be included in the groups to benefit from their expertise, but it should not be necessary for NRAO to have to pay for their time which can be counted as normal community service. The mechanism for the MDC to participate in the engineering effort for MMA Development will be by NRAO funding hardware and software development projects at BIMA and OVRO. The following points came out ofa discussion of the organization of these projects. As a general philosophy, the best development projects will be those that the Universities want to do even in the absence of MMA funding. However, the tight budget will mean that projects will have to have clear potential benefit for the MMA. NRAO needs budget and schedule control of these development projects so that they will fit into the overall MMA budget and schedule. It is suggested that each project selected for funding by the MDC Executive Committee be defined in detail in a discussion between the responsible NRAO person and the BIMA or OVRO "principal

investigator". A brief Proposal defining the project and its schedule and budget would then be written by BIMA or OVRO and funded by NRAO as an annual, renewable Contract. Where the Universities hire new people asa result of taking on a development project, it will be best if these people are University employees rather than NRAO employees. OVRO would like to start recruiting for people as soon as possible and is willing to do this given encouragement from NRAO, even before funding arrives. The next step in getting projects started seems to be for NRAO to put together a plan for the whole development phase, incorporating where appropriate those projects of interest to BIMA and OVRO, and to present this plan to the MDC Executive Committee for approval.

4. Discussion of Specific Development Projects

Radiometric Phase Correction
This is an excellent candidate project with both BIMA and OVRO having plans for continuing work. Measurement of the profile of the water line, with a goal of attempting to estimate the vertical distribution of the water vapor, seems an obvious next step. D. Plambeck showed some modeling results which suggest that even on the 5000 m site the 183 Ghz water line may be saturated for a significant fraction of the time, so the first part of any project should probably be a study of which line is best for the MMA. With both BIMA and OVRO planning significant workin this area, it would be very helpful if the two groups could get together and come up with a coordinated project for MMA funding.

Correlator
The proposed new OVRO correlator is designed to allow rapid development and to be able to take advantage of future improvements in digital VLSI technology. It would be a good design choice for an interim correlator for the MMA, but it is less clear that it is suitable for the full, final correlator. This should be discussed by the Working Group. NRAO already has a design and the chips for an interim correlator based on the GBT chip. It seems likely that the OVRO and MMA correlators could use the same digitizer and this possibility should be investigated. BIMA also wants to work in the correlator area and it would be helpful if the two groups could coordinate.

Antenna Thermal Studies
There is a window-of-opportunity to instrument the new BIMA antennas before they go into operation in June, so this project will move ahead immediately. OVRO is also interested in the data and it is possible that J. Lamb, who worked on the original BIMA thermal instrumentation, will participate.

Software
This is a very complicated area with both BIMA and OVRO having well-thought-out plans for both current and future work on their respective systems. The MMA Computer Working Group will have to look at both plans and provide advice on what do in the area of software development.

Receivers

All of the receiver issues on the BIMA and OVRO lists are important questions for the MMA. Since the MMA is planning to squeeze many receivers into a single dewar, an important question to be addressed by the quasi-optical approach proposed by OVRO is "how compact can the quasi-optics be made".

Agenda for BIMA-NRAO-OVRO Meeting on MMA Development, 3 May, 1997 Attachment 1

0900: NRAO plans for the Development and Construction of the MMA.

1000: BIMA/OVRO Plans for the California Combined Array.

1100: Mechanisms for organizing the BIMA/NRAO/OVRO interactions.

1200: Lunch

1300: Discussion of possible MMA development projects at BIMA and OVRO.

>From prior discussions, possible projects include, but are not limited to:

Development and demonstration of a 183 GHz radiometric phase calibration technique.

Work on methods of producing linear and circular polarization in the receivers. For circular, also consider generation in the IF or backend.

Study the design features needed to make the MMA a useful total power instrument.

Fiber optics issues, including a low cost transmitter/receiver design.

Local oscillator work.

Correlator design work.

Software work.
- User interface
- Data Archiving and Calibration
- Imaging

Other suggested projects.
- Dish thermal characteristics
- Trajectory tracking servo systems
- Atmospheric physics (where is the turbulence)

1600: Further discussion on BIMA/NRAO/OVRO interaction mechanisms.

1700: Summarize recommendations

1800: Finish meeting.

Attachment 2

Key Considerations for MMA Development/Construction Plan

Budget

NSF Plans: Development 1998-2000, Construction 2001-2006. MMA plan must match this.
NSF must have Construction cost estimate in 1999 to get 2001 money.
Total budget is very tight - Development phase now comes out of Construction budget.
Antenna cost critical. Try to make production run build-to-print.
Requirement for non-NSF budget partners complicates all planning.

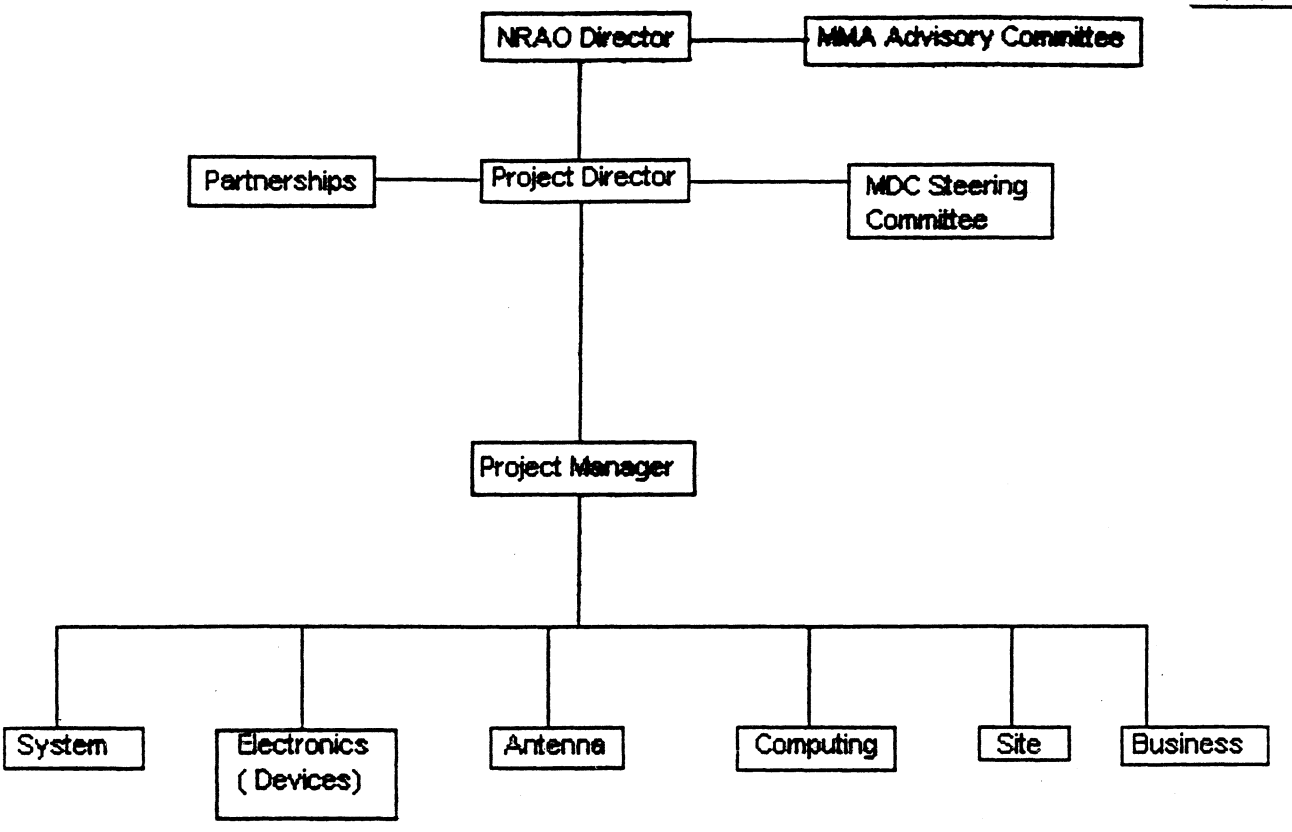
Personnel

NRAO responsible for Development, Production, Commissioning, Operation. Must use Development phase to build up in-house groups.
NRAO needs expertise of BIMA and OVRO people. Obtain this using Working Groups and by doing some development work at BIMA and OVRO.
Chile site is very difficult. Use Test Array to minimize expert work needed in Chile.
Because of budget uncertainty, NRAO must use current employees in current locations to maximum extent possible for Development.

Schedule

Get 2 prototype antennas early enough to test them adequately before production run.
Get initial interferometer working early enough so that first antennas can be tested in interferometer mode before production run.
Get test array running early enough so that everything can be debugged and tested before it has to work on Chile site.

Attachment 3



Attachment 4a

VERY ROUGH FIRST DRAFT

Strawman Schedule for MMA Construction as of 3-24-97

ACC=Array Control Computer
OSF=Operations Support Facility (San Pedro)

1997

July?: Decision of Correlator Architecture
Oct: Prototype Antenna RFP

1998

Jan: Start Antenna Contract
Jan: Begin design of prototype receiver
Jan: Begin computer/software systems
Jan: Begin LO and fiber optics system
Jan-Dec: Correlator Architecure Design
Jan: Start (part-time) ACC/correlator software design
Apr: Soil Test on Chile Site
June: Select project A/E
June: Begin design of civil works
Oct: Antenna vendor completes antenna design

1999
Jan-Dec Design chip and fabricate chips for correlator
Jan-Dec Design Boards for Correlator
June: Deliver Antenna 1
June: Deliver prototype receiver to test site
June: Final costing for Array
Aug: Antenna 1 single dish testing begins

2000
Jan: Deliver 2 station interim correlator to test array
Jan: Start ACC code
Jan: Deliver Antenna 2
Jan: Deliver 2nd prototype receiver to test site
Apr: First Fringes on prototype interferometer
Jan-June Fabricate boards for final correlator

Oct: Start Construction project (phase II)
Oct: Deadline for Obtaining Chilean Land for High Site/OSF
Dec: Final Antenna RFP

Attachment 4b

2001
Jan-Dec: Integration and Testing of Final Correlator
Jan-Dec: Construction of OSF
Jan: Start High Site Construction
Feb: Start Final Antenna Contract
Oct-Dec: Antennas 3,4 to Test Array

2002

Jan: 1 IF Pair of Final Correlator to Test Array
Jan-Dec: Test Correlator with ACC
Jan-Dec: Antennas 5-12 to Chile

2003

Jan-Dec: Antennas 13-20 to Chile
Two antennas to California High Site
July: 1 IF Pair of Final Correlator to Test Array

2004

Jan: First Science Operations in Chile
Jan-Dec: Antennas 21-28 to Chile

2005

Jan-Dec Antennas 29-36 to Chile

2006

Jan-June Antennas 37-41 to Chile
July Antennas 1-4 from Test Array to Chile

Attachment 5a

High Site Current Status

- 4 sites presented informally to USFS
- 2 sites rejected
- Weather stations since June '96
- We favor Upper Harkless Flat
- UHF access road study complete
- Soil study initiated
- Transporter specifications developed & costing requested
- NRAO tipper operational at OVRO
- Tipper permit due May 9
- Tipper to UHF late May

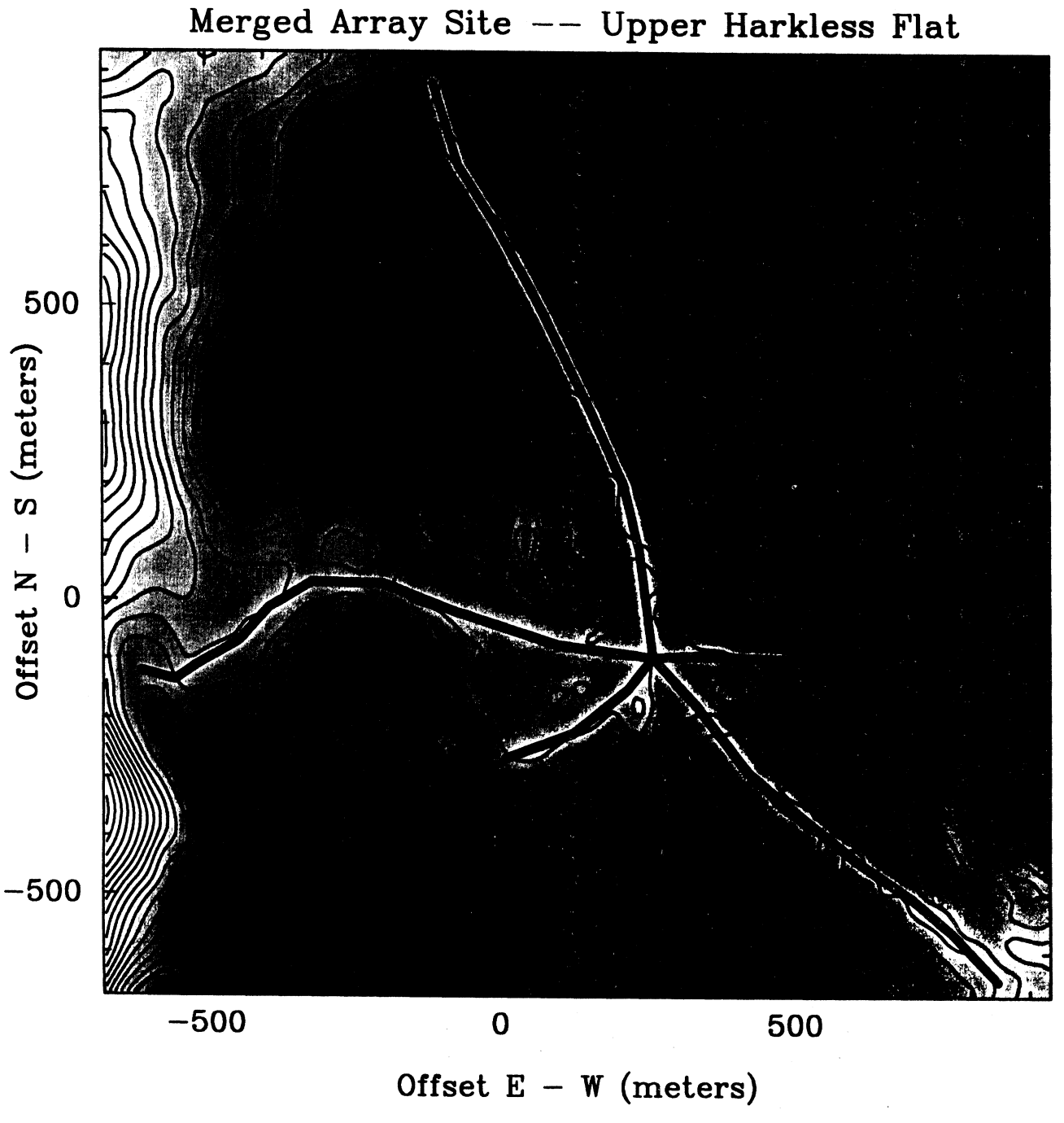
Attachment 5b

High Site Future Work

- Detailed Site Plans
  - Telescope locations
  - Buildings
  - Power
  - Water/sewer
  - Communications

- Apply for USFS Special Use Permit
- Prepare funding proposal

Attachment 6



KEY TO CONTOURS

Thick Contours: 2300, 2400, 2500, 2600, 2700 m

Thin Contours: steps of 5m from 2605 to 2695m

Dashed Contours: steps of 10m up from 2700m

Attachment 7

Partial list of projects OVRO is interested in working on

Major Projects

1. Dual polarization and sideband separation receivers

2. User interface software

3. Wideband correlators

4. Calibration and data management software

Smaller Projects

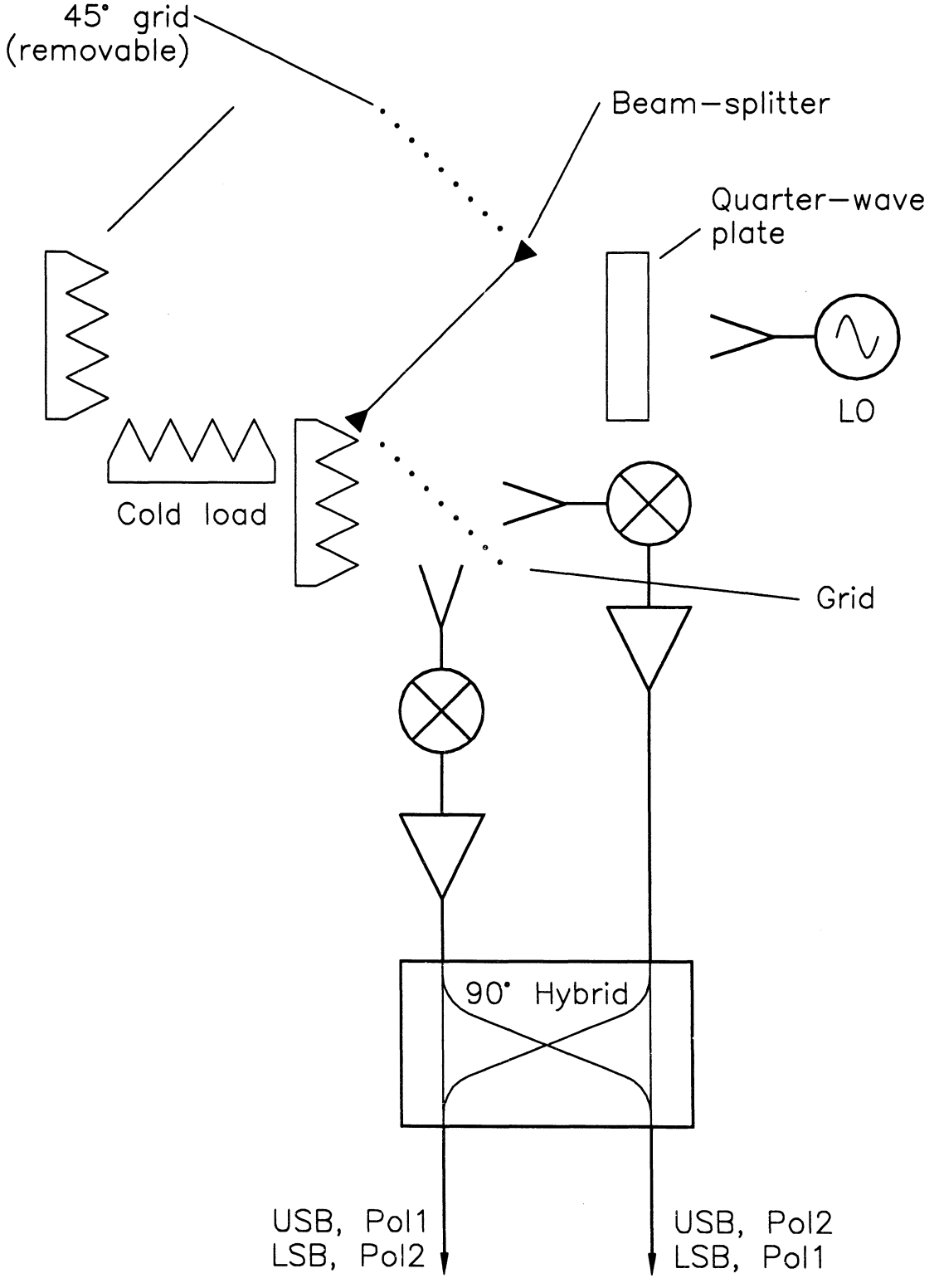
1. dish thermal characteristics

2. trajectory tracking servo systems

3. nature of atmospheric turbulence and phase correction algorithms

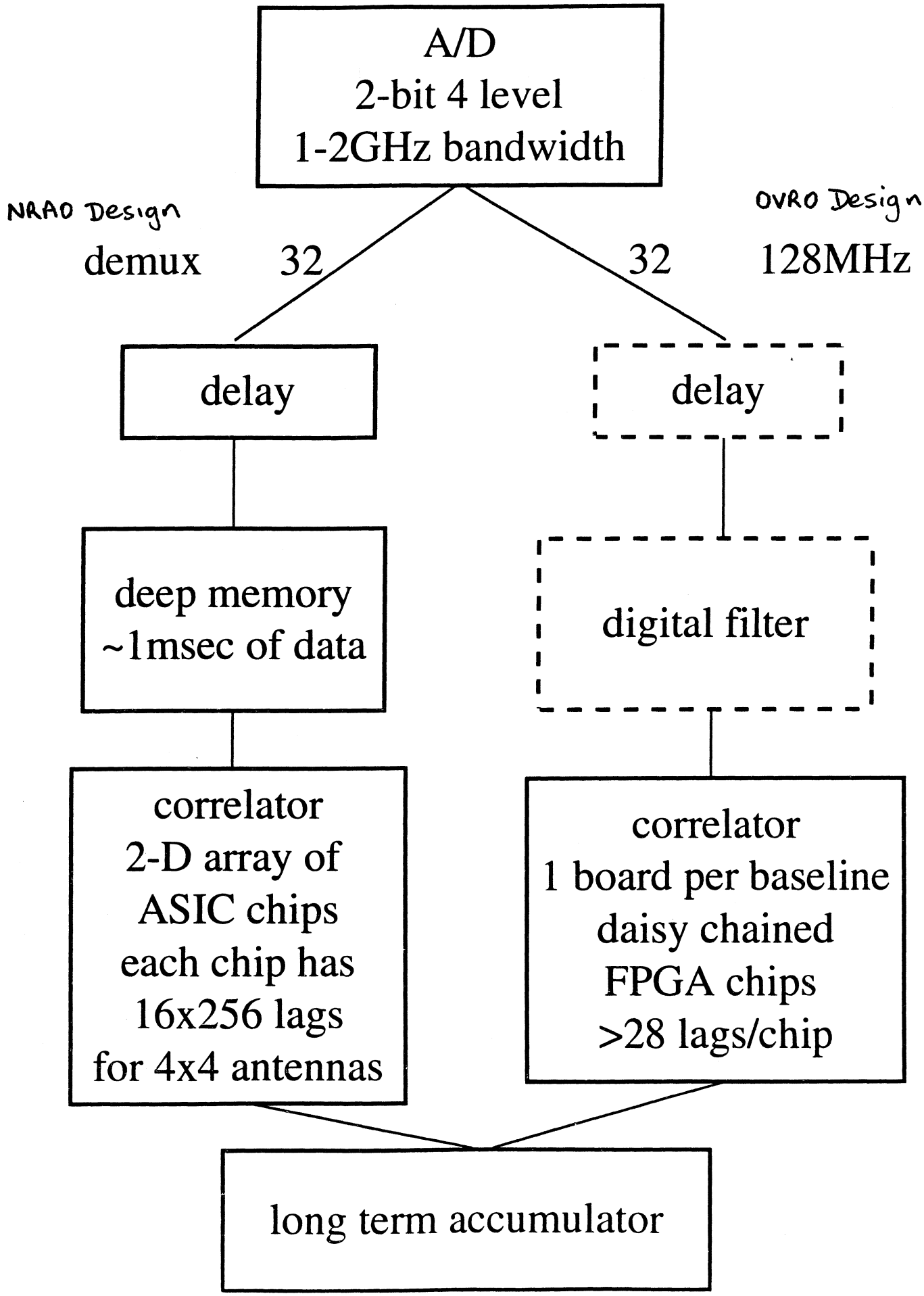
Attachment 8

Concept of a Quasioptical Image-Separation/Dual-Polarisation Receiver



Attachment 9

Wide Bandwidth Correlator



Attachment 10a

Array Control Software

- Complex instrument needs high quality software to build, debug, maintain & operate
- Next generation of current OVRO system
- Assumes color graphics & TCP/IP platform
- Specific UI requirements:
  - *Multi-platform interface*
  - *Multi-user, location independent access*
  - *Web based*
  - *Low bandwidth (modem) adequate for almost all functions*
- Developing monitor & control separately
- Java chosen for UI
- Monitor prototype developed using Unix server & Java clients

Calibration System Features

- Integrated with DBMS
- Provide batch (pipeline) & interactive processing
- Both batch & interactive use same code
- Extensible/modifiable by non-programmers
- Output in format to feed imaging software
- Intelligent system with learning & fault detection capability
- Possible Approaches
  - *Powerbuilder*
  - *IDL*
  - *Java*
  - *C++*
  - *Fortran*

Attachment 10c

Data Archive Features

- Commercial relational database integral part of instrument
- All astro & engineering data on DBMS (no files)
- All data online & continuously accessible
- Header compact by storing data in a highly normalized form
- Commercial software ensures keeping up with hardware & OS changes
- Commercial software supplies backup, restore & integrity mechanisms

Attachment 10d

Data Archive Plans

- Re-evaluate for CUMA & MMA data rates
- Evaluate gains from multi-processor computers
- Reassess vendors (Oracle, Sybase, Informix…)
- Investigate object databases

Attachment 11

BIMA Proposal for MMA work done through the MDC

The following is a list of projects that BIMA would like to do under the auspices of the MDC for the MMA

1) Atmospheric Phase Correction

We propose to investigate prototype systems at 183 GHz and 22 GHz which would be useful for the merged California Array and would be tested under the full range of observing conditions, including those appropriate for use at the MMA site.

2) Polarization

We would like to do the development work on how to provide the MMA with polarization capability. This would include an evaluation of whether linear or circular polarization is better and whether it is possible to do the combining for circular polarization in the IF.

3) Cable Phase Measurement in Fiber.

We would like to develop the workings of the system to be used for cable length measurement for the MMA.

4) Accurate Radiometry

We would like to develop the hardware necessary to make it possible to do 1 - 2 % accuracy on amplitude measurements.

5) Correlator

We would like to have some, as yet undetermined role in the development of the MMA correlator. This would include system design and board layout.

6) Real-time Data Transfer

This would include data archiving, and on-line data access.

7) Image Processing and Analysis

We would like to provide intelligent systems development for processing of MMA data including advanced visualization software, and parallel processor synthesis imaging algorithm development.

8) Antenna Construction

BIMA expertise on antenna design and construction should be part of the overall MMA plan.

9) High Frequency Transistors

We would like to work on high-frequency transistors, to be used in place of superconducting devices for the lower frequency MMA bands.

This list may not be complete, but contains most of the items we have identified to date.

Illinois MMA work

Attachment 12

Crutcher

* Data archive and retrieval. System from electronic proposal to observe file to uv data to final images should be seamless, with everything being in the archive. Given the commitment by NRAO to AIPS++, this should be in the AIPS++ format and system. We will build on our development of the BIMA real-time data transfer and data archive system and our extensive experience with AIPS++ to help design and develop the MMA system.

* Expert systems. The MMA is a complex insrument which has been (partially) sold to the astronomy community as providing everything for the mm community. This will require a greater ease-of-use than present synthesis array instruments. Building on our experience with mm-array data processing and AIPS++, we will help design and build expert systems that will provide first-order fully processed images automatically to the astronomers' desks.

* AIPS++ continued development. We will continue our activities in AIPS++ distributed computing, parallel-processor computing, and image analysis and visualization with particular attention to the MMA.

Sutton

* Atmospheric phase correction. We would work with other university teams on development of phase correction schemes using 183 GHz (or 22 GHz) radiometry.

* Transistor amplifiers. If amplifiers are adopted instead of SIS mixers for the lower frequency bands, we would help on device development and integration into receiver systems.

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Attachment 13

I'm trying to get our list of interests together for the MDC meeting -- what's missing from the list below? Or extra, for that matter?

Notes for MDC meeting

Areas of interest to Maryland

1) Atmospheric phase corrections (hardware for phase measurement, e.g. correlation receiver; experimental verification of techniques; software associated with hardware and software)
2) Fiber transmission line properties (suitability of multi-mode fibers)
3) Wideband analog correlators
4) Software related to real-time scheduling
5) Expert systems, as applied to enhancing observational results (scheduling, phase corrections, etc.)