MILLIMETER ARRAY/ALMA-US
DESIGN AND DEVELOPMENT

MONTHLY REPORT
MONTH END
AUGUST 2000

1 Executive Summary

Much progress was made on the ALMA project during the month of August. One major event was the completion and occupancy of the new addition to the Tucson office and lab space. This new space means that all of the ALMA personnel in Tucson are co-located. Additionally, needed laboratory space is now available making room for the increased development activities leading to both the test interferometer and production prototypes. The "ALMA Annex" has now been vacated.

Antenna development activities continue to progress towards a November 15, 2000 CDR. With NRAO approval, Vertex has commenced procurement of long lead-time items including azimuth and elevation position encoders, reflector panel material and tooling for the CFRP backup structure.

The cryogenic compressor for the test interferometer, which was completed last month, has now undergone extensive performance tests. These tests demonstrate this device meets all of the performance requirements for the test interferometer as well as the more stringent requirements of the ALMA array.

The earlier successful demonstration of high-speed photo-diodes, intended for the photonic LO reference, creates an opportunity to dramatically simplify another vital part of the test interferometer. Plans for testing of the prototype antennas include extensive use of millimeter wave holography using a tower mounted terrestrial beacon. We now plan to use a photomixer rather than a conventional Gunn oscillator for this beacon. Use of the photomixer simplifies the beacon and requires only an optical fiber connection to the tower. The same laser synthesizer used for the LO system can be used to drive the beacon.

We continue to plan to use the 12M antenna at Kitt Peak for testing of the ALMA control software. The University of Arizona, who control this facility under a loan agreement, have been very cooperative in providing the necessary time for these valuable tests. A test run is expected to take place in December.

2 Programmatics

2.1 Financial Statement

[Not Included.]

2.2 Personnel

The ALMA Project staffing is reported by WBS Level-1 category based on the joint project WBS. The total number of full-time equivalent employees was 59.3. As planned during this period, approximately ten personnel were transferred from 12M operations to the ALMA staff. They have been a significant help maintaining the development schedule.

3 Meetings and Memos

3.1 Meetings held in August

ALMA U.S. Division Heads Meetings -August 7, 14, 21
Minutes are distributed to all ALMA U.S. Division Heads via email

ALMA Scientific Advisory Committee Teleconference - August 07
Minutes are available at URL: http://www.alma.nrao.edu/committees/ASAC/index.html

ALMA Site Development Teleconference - August 16

ALMA Executive Committee Face-to-Face - August 24

ALMA Joint Division Head/Team Leader Meeting - August 28
Minutes are distributed to all Division Heads and Team Leaders via email

ALMA Joint Receiver Development Group Teleconference - August 30
Minutes are available at URL: http://www.alma.nrao.edu/committees/jrdg/index.html

ALMA/NSF Meeting - weekly teleconferences

ALMA Imaging and Calibration Meeting - weekly teleconferences

ALMA Executive Committee Meeting - weekly teleconferences

3.2 Meetings planned for September

ALMA Photonics Meeting - September 01
ALMA U.S. Division Head Teleconference - September 5, 11, 18, 25
ALMA Holography Teleconference - September 06
ALMA Joint Receiver Development Group Face-to-Face Meeting - September 07-08
ASAC Face-to-Face Meeting - September 09-10
ALMA US DH Face-to-Face Meeting - September 21
ALMA Test Interferometer Bi-Weekly Teleconferences
ALMA U.S. DH Meeting - weekly teleconferences
ALMA/NSF Meeting - weekly teleconferences

ALMA Imaging and Calibration Meeting - weekly teleconferences
ALMA Executive Committee Meeting - weekly teleconferences

3.3 ALMA Memos Issued in August

ALMA Memo 321	Receiver Amplitude Calibration for ALMA Richard Plambeck
ALMA Memo 320	Strawperson Donut/Doubling-Ring Configurations M.S. Yun & L. Kogan
ALMA Memo 319	Photonic Local Oscillators for Radio Astronomy Signal-to-Noise Issues Bill Shillue
ALMA Memo 318	Amplitude Calibration at Millimeter and Sub-millimeter Wavelengths Jeff Mangum
ALMA Memo 317	Comparison of the Pointing Error Effect on the Image Quality for Two Configurations and Two Source Types L. Kogan

4 Technical Progress Reports

4.1 Antennas

During the month the antenna group continued supervision of the contract for the prototype antenna with Vertex Antenna Systems. ALMA staff were present at the contractor's facility in Duisburg, Germany on 22-24 August. The contractor has commenced procurement subcontracts for long-lead items including azimuth and elevation position encoders, reflector panel material and rough machining and the mold for the CFRP reflector backup structure tooling. NRAO reviewed and approved the procurement specifications for these components. The contractor completed a new computer finite element model for the antenna including a more detailed thermal model required to refine the estimated thermal performance of the antenna. This model was provided to NRAO for checking. The design of the various platforms and access stairways on the antenna were also provided to NRAO for checking conformance with the various OSHA regulations.

Within the NRAO antenna group work continued on the design of various pieces of antenna equipment including the optical pointing telescope and the subreflector nutator. Updated versions of several antenna interface control documents (ICD), including the ICDs for the receiver, monitor and control system and transporter were in progress in collaboration with the European antenna group.

During the next month the contractor will continue work on the antenna design, working towards the Critical Design Review on 15-16 November.

4.2 Front End

A major objective of the SIS mixer development was achieved with the successful test of a 211-275 GHz mixer with integrated preamplifier for the 4-12 GHz IF band. In this experiment, the only gain within the dewar was the preamp, so some improvement in performance is expected with a cooled postamplifier. The receiver temperature with the wideband IF was the same as that measured with the conventional 1.2 GHz IF, but the effective bandwidth was 8 GHz instead of 1 GHz; the new system thus meets the ALMA specification. The particular mixer tested with the preamp was tuned slightly below the ALMA RF band, and was not quite as good in noise performance as a typical mixer (excess of about 10K DSB); this will be corrected with a differently-tuned mixer chip.

We have received delivery of newly-designed thin film capacitors from UVA for use in SIS mixer bias-T's, particularly for the 211-275 GHz sideband-separating, balanced mixers. These are much smaller than commercially-available capacitors of comparable capacitance and may be useful in high-frequency amplifiers as well.

The blocks for the 211-275 GHz sideband-separating, balanced mixers are being fabricated in the Charlottesville shop and are expected to be complete before the end of September, at which time the first attempt to mount and test a chip will begin. The test hardware and software are complete and ready. Work is continuing on improved optics for the test system, including matching layers for windows, lenses, and IR filters. Some experiments in machining the plastic materials are in progress in the shop.

Work continued jointly with collaborators at the Herzberg Institute in Canada on a memo concerning the design of sideband-separating, balanced mixers using split-block hybrids and splitters as an alternative to fabricating such structures on a chip as is done for the 211-275 GHz design. A test structure for 75-110 GHz which incorporates a waveguide power divider/combiner was fabricated as a split block and successfully tested. This will be suitable for use both as a splitter for SIS mixers and as a power combiner for LO driver amplifier chips. It is suitable for scaling to at least 720 GHz. All these waveguide components have been extensively modeled and optimized using Quickwave simulation software, and the performance of the test pieces closely matches the predictions.

A preliminary analysis of an SIS mixer capable of covering 86-116 GHz was carried out. This is an alternative to using an HFET amplifier, which although it is intrinsically single-sideband and available now with noise temperature comparable to an SIS mixer, has higher 1/f gain noise. The result is that satisfactory input and output match can be obtained over about 84-120 GHz with fixed-tuned structures. So far, the analysis has concentrated mainly on the tuning structures; in September, work will be done on matching SIS junctions to the structure. If this can be done satisfactorily, then the design may be completed and fabricated.

During this period the ALMA laboratory in Tucson moved its operations into a new facility that is a vast improvement. The laboratory space has expanded and we are now

well situated to construct both the equipment needed for the test interferometer and the initial receivers for the ALMA array.

The last month has been very productive. The evaluation receivers have continued to be constructed and the cryogenic compressor has completed its initial tests. The compressor is now complete and has a computer interface that has been designed and tested by a joint program between the monitor and control system and the receiver group. The production receiver program has also been quite successful during the last month. A meeting of the Joint Receiver Design Group (JRDG) is planned for September that is expected to finalize the basic design of the front end subsystem.

The photonic LO system is advancing rapidly. A meeting was held in Duisburg to review that progress of the ALMA photonics effort and it was clear that the European development program for the high frequency photo detector was well advanced and on schedule. A similar meeting will be held in Tokyo in November to review progress on the whole ALMA effort, including the Japanese. Some recent spectacular results were announced by the Japanese at the MWP 2000 conference in Oxford in September that are directly relevant to the ALMA project.

4.3 Local Oscillator System

Local Oscillator Multipliers

The results of extensive phase and amplitude noise testing of a prototype LO driver chain were documented and released as ALMA Memo 311. Testing the temperature dependence of phase and the associated long-term phase drift characteristics began, and the preliminary results are satisfactory: the long-term drift is well within the budgeted specification. More tests will be conducted in September. The Labview software needed to perform the required equipment control has been expanded.

There have been extensive discussions with the systems group to reconcile the content of the Project Book LO Multiplier section with the overall requirements and plans. Work has begun on the local oscillator/receiver ICD.

Photonic LO and Test Interferometer First LO

A new fiber laser was ordered to serve as the master laser for the Test Interferometer. Another laser of the same type, remains at the factory undergoing repairs; this has limited the laboratory work that we have been able to do lately. Lasers of the necessary very narrow line width are difficult to obtain, and this model is being discontinued. It took some effort to get the manufacturer to accept an order for another one. (For the array, other types of lasers are under consideration.)

Meanwhile, work continued on the first LO for the test interferometer, primarily design of control mechanisms and circuits for the Gunn diode oscillators.

The TI site optical fiber distribution plan was worked out and agreed upon with the site infrastructure group in Socorro.

A new responsibility was undertaken by the photonics group, namely providing the transmitter for holography. It is now planned to have only a photomixer on the tower, coupled via a waveguide mount into a horn antenna. The photomixer will be driven over fiber by one of the laser synthesizers already being built for the first LO reference. The photomixer will be identical to those used to generate the LO reference for the front ends.

John Payne provided some consulting to the AMIBA project in Taiwan. They are intending to use a photonic LO for their 3 mm wavelength array, and they may use photomixers identical to ours.

Local Oscillator Reference

CENTRAL REFERENCE GENERATOR

Completion of the FPGA code development was held up because the newest upgrade of Foundation Express (The FPGA simulator from Xilinx) would not run under Windows 95 and Windows 98 had to be installed on the Lab computers. The final definition of power supply voltages for the LO Reference modules needs to be made.

SECOND LO SYNTHESIZER

Development continued on a microwave divide-by-512 prescaler based on an HP divider IC which works up to 16 GHz. This circuit will be part of the counter for the Second LO Synthesizer. A single stage divide by eight prescaler worked fine, but there was difficulty cascading two stages. The likely solution is to use a 1.3 GHz divide by 512 counter prescaler after the first HP prescaler, thereby performing the level conversion at the same time. Suitable components from Motorola and NED are being investigated.

4.4 Backend Subsystem

Data Transmission Fiber Optic Link

Various synchronization techniques were compared and testing of some of these ideas on the Xilinx evaluation board will be done over the next several weeks. A schedule for completion of the digital link was developed.

Downconverter

General Microwave 0.5-4 GHz and 2-18 GHz digital attenuators were received for testing. Testing phase vs. attenuation is critical for the design. Seven responses to RFQs for a 1.5-2.5 GHz isolator for the Downconverter were received and evaluated.

A much revised and enhanced block diagram of the Downconverter bench prototype was prepared and the draft Downconverter specifications were revised.

Vendor data for improved total power tunnel diode detectors was searched, and some useful information was obtained from an engineer at a detector manufacturer. Data and application notes on sigma delta and SAR digitizers was found from Maxim and Cirrus.

The Downconverter schedule and work plans were revised with tasks updated through the bench prototype testing and part way into the field unit fabrication for the test interferometer.

4.5 Correlator

The FIR filter printed circuit boards were received, and a kit of parts was sent to the ALMA lab in Tucson for board population. The first board is expected back by the end of September. There have been problems with procuring many standard parts, with many components either having long lead times or being on indefinite allocation.

Design layouts were completed for the Long Term Accumulator Card, Station Card, and FIR Filter/Station test card. Work continued on the design of the Correlator Card.

The custom correlator chip initial design is nearly complete. It is expected that in mid-September there will be exhaustive simulation of the whole design, for which purpose a NRAO engineer will travel to the designers' site to participate in the simulation.

Work continues on the operational software for the test correlator. The test modes have now been implemented. It is now possible to synchronize the correlator output to the external 48 msec timing events.

4.6 Computing

In August, the NRAO group on behalf of both partners submitted a proposal to the University of Arizona for time to continue our software-testing program on the 12m antenna. We requested 8 days starting December 1. A progress meeting with EIE following the EIE control system PDR was held. The Science Software Requirements (SSR) committee turned their memo #293 into a requirements list document and circulated it for comment. The Use Cases generated at the Grenoble meeting were circulated for comment to the committee. Some high-level analysis and design (A&D) work (e.g., UML sequence diagrams) based on the existing use cases continued. In the Software Engineering (SE) area, the Rational Rose CASE tool installation kits were distributed to ALMA sites in both Europe and the US. A standard document template was prepared but not yet distributed. A paper on software development process, methodology, and tools was distributed to the whole project for comment. The ALMA Common Software (ACS) group distributed a pre-release of version 0.0 prerelease to NRAO/Socorro and IRAM for installation testing and demonstration purposes. Demonstrations over the web to interested parties were also carried out. The BACI component of ACS 0.0 was ported to VxWorks. A 2-day visit to the Slovenian development team of the underlying CoCoS softwarewas carried out. Planning in earnest for the 12m antenna tests commenced. Replies to comments on the architecture document were distributed. In the Control Software (CS) area, the second revision to the AMBSI M&C interface board was evaluated, and a third revision was sent to

manufacturing. The Tucson cryogenic system was given a standard M&C interface, and successfully monitored and controlled through it (including LabView based logging software for the pressure sensors). Work on design documentation for a late-year design review continued. Personnel from IRAM and NRAO determined how to split the implementation of software elements related to mount control. A scheme for automatically generating HW/M&C ICD's from a common XML source was investigated. Work towards ICD's for the 2nd LO and central reference generator was begun.

In the Correlator Control Software (CCS) area the preliminary implementation of the 100MHz was completed and tested. In collaboration with a hardware engineer, changes were made to allow sub-integration of the test correlator to be synchronized with the system-wide 48ms timing events. Changes to the design document were made in preparation for a CDR later this year.

Next Month

The SSR committee will meet in Berkeley to discuss the requirements list and use cases. ACS 0.0 will be released to the project. Adoption of a software problem reporting system using infrastructure already implemented at ESO will be discussed. A standard document template and C/C++ coding standards will be distributed and discussed. The third revision of the AMBSI will be evaluated.

4.7 Systems Engineering

During August, we continued to refine the design of the holography system and confirmed some of the choices in an international teleconference. A formal Critical Design Review is scheduled for October 10. One important decision was to generate the transmitted signal photonically: only a photomixer and horn antenna will be mounted on the tower, driven over optical fiber by one of the laser synthesizers being built as an LO reference for the astronomy receivers. (See also report under 4.4.1 above.) Other design choices included the selection of observing frequencies (80 and 104 GHz); methods of mitigating multipath interference; and receiver LO frequency control method.

We also contributed to the design of the optical pointing telescope by selecting the overall system configuraton and participating in two local meetings. The SE group will design the control electronics for the telescope and procure a fiber optic link for the video signal.

We devised a numbering scheme for engineering documents like drawings and specifications, and put it into effect for the U.S. side of the project.

A memo giving specifications and engineering guidelines for d.c. power distribution within the Test Interferometer was prepared and distributed to the appropriate engineers.

In connection with the antenna contracts, we reviewed changes to the front end interface specification; and we provided an a.c. power budget for the electronics.

Finally, we supplied comments on several design documents of the computing division.

4.8 Imaging and Calibration

I. Imaging - Configuration Studies, Site and Water Vapor Radiometry

The imaging and calibration group held several phone meetings during August, with the agenda, indeces and linked documents to be found at:

http://www.cv.nrao.edu/~awootten/mmaimcal/

A. Configuration Studies

The simulation efforts for the primary ALMA array have reached a point where the basic simulation procedure is agreed upon, and results exist for parameters agreed upon at the March face to face meeting for presentation to the ASAC. Steve Heddle in UK is making good progress on the imaging simulation.

John Conway, Min Yun and Brian Butler advised him on this effort during August. A telecon for the configuration working group was held on 23 August to discuss the results thus far and how to proceed. At month's end a good library of results was available, and the simulations were proceeding to study of differences in images formed by different array designs.

The strawperson configuration memo, including the complete layouts and initial examples of imaging performance, was finished by month's end as ALMA Memo No. 320 by Yun and Kogan. Min Yun left the project at month's end to take up a position at the University of Massachusetts at Amherst; he plans to continue his ALMA activities as he can.

B. Atacama Compact Array

The most pressing issue for now is the definition of and imaging test for the Atacama Compact Array (ACA). During August, the definition of the array converged on several similar strawman designs. A protomemo by Guilloteau suggested 8m antennas, owing to similarity in receiver cabin design possibilities and good calibration sensitivity, particularly in the submillimeter, while u,v coverage was not so suitable as might be with a 6m telescope. A standalone array of 10, 8m telescopes resulted from these considerations. Another point of view stresses getting good u,v coverage by employing 6m telescopes. A memo by Welch suggested a standalone array of 12 x 6m antennas by month's end. Imaging tests commenced during August for the ACA, using arrays of 6m and 8m antennas to judge relative performance. Yun's single pointing simulations to evaluate the imaging performance of the 6m versus 8m antennas for the ACA have been indeterminate so far. These simulations and other discussions within the configuration group suggest that simulated mosaic observations are truly needed. Yun pursued these efforts within the aips++ and Classic AIPS programs, and Morita also pursued studies of the Compact Array. By month's end a few things were clear: simulations with reasonable errors are needed, but that in imaging simulations dynamic range is limited by the pointing errors of the larger antennas in the array while fidelity index can be improved considerably by including the compact array.

C. Site

Radford updated web pages and data files for radiosonde and tipper data through July. Radford and Butler also worked on reduction and analysis of radiosonde data, and production of a paper describing these data. Hydrodynamic airflow simulations with Dave DeYoung (NOAO) continue.

Radford also began testing the new Inmarsat M4 terminal for delivery to the site later this Fall.

Butler revisited a memo in preparation describing possible locations for the compact array on Chajnantor, and Radford and Butler coauthored Sakamoto's ALMA Memo No. 322 on weather at Pampa La Bola and Chajnantor, which appeared in late August.

II. Calibration

A. Interferometer/Antenna Amplitude Calibration

Mangum finished and issued a memo on amplitude calibration as No. 318 in the Memo Series. A two-load chopping scheme was found to have the potential for reaching 1% accuracy in all bands, as specified by the ALMA Science Advisory Committee. A study by Plambeck (No. 321) reached similar conclusions. These memos formed the basis for a recommendation by the Imaging and Calibration Group that ALMA pursue studies of two load chopping schemes of amplitude calibration, with particular emphasis on a location behind the secondary. Several concerns about this system need to be addressed, however. It appears that the 1% accuracy sought by the ASAC will challenge any scheme.

B. Pointing Calibration

Mangum continued work on his memo on pointing of the ALMA antennas.

C. Other

Mangum pursued the thorny question of "how small a field do we want to image at the maximum scanning rate of the ALMA antennas". The current Vertex design indicates a turn around time of 0.8 seconds assuming a 30'/sec scan rate and a scan time of >2 seconds in OTF mode. Note that this implies a >1 degree scan length at the maximum rate. In an unpublished but oft-cited work, Holdaway found that OTF total power observing is as good as or better than beam switching for optimal sky subtraction when one could OTF map at the maximum slew rate (1 deg/s) and a 0.2 second turn around time. So, Vertex is within a factor of <~6 of meeting Holdaway's simulated break-even point.

III. Science

A. ALMA studies, including the ASAC

Butler and Wootten presented a paper on ALMA capabilities for the detection of Extrasolar Planets at the IAU symposium No. 202 on this subject. ALMA can directly image young systems including the star, disk and large planets, imaging their dynamics and chemistry on few-AU scales for nearby systems. ALMA will directly image the gas and dust in more evolved systems, revealing the presence of planets through gaps in the structure. Very young proto-Jupiters, free floating or tied to a planetary system, could be detected with reasonable integration times out to the distances of the nearest star-forming

clouds. As an evolved planet orbits its parent star, the latter will undergo reflex motions measureable by ALMA; these studies favor discovery of planets at large orbital radii and complement radial velocity searches, recently productive at optical wavelengths.

Wootten presented a report on ALMA at the Observatory Reports session of Division X, and represented the project at other IAU venues.

Final work continued on the volume summarizing ALMA Science from the meeting last October. A paper on ALMA observations of distant galaxies was written for publication in the proceedings of the 'Gas and Galaxy Evolution' conference of late Spring.

Plans for the face to face ASAC meeting in Berkeley, including the agenda and reading material were finalized by Wootten.

B. Imaging and Calibration

Plans for next month

Imaging and Calibration will sponsor the ASAC face-to-face meeting in Berkeley early in the month, bringing issues of concern to the project to the attention of its scientific committee for advice and resolution. As the ASAC Report is developed, we will convey it to the rest of the project and react to the recommendations of the committee.

Configuration work will continue, with a focus on finishing a set of the simulations and distilling the results into a recommendation on array design. Incorporation of various sorts of errors into the simulations can begin, and the appropriate nature of these will be determined as we assess the results so far and the capabilities of simulation software.

Work also continues on the characterization of the ACA.

Issues and concerns

During September we will continue to seek a replacement for Min Yun, though it will be difficult to match his insight and productivity. US resources in millimeter astronomy have shrunk, and there are few new students available.

MILLIMETER ARRAY/ALMA-US

PROJECT STAFFING

MONTH END AUGUST 2000

WBS Task Name	Number Of Persons Participating in Activity*	Full-time Equivalent Employees
Administration	10	6.8
Site Development	1	0.0
Antennas	4	3.0
Front-End	22	15.8
Local Oscillator	11	8.8
IF and Fiber Optics	7	6.0
Correlator	5	4.0
Computing	8	7.5
System Integration	5	4.5
Calibration	3	3.0
TOTAL:	76	59.3

* Several persons in this column are counted two or more times. These particular individuals are involved part-time in more than one activity.