MILLIMETER ARRAY/ALMA-US
DESIGN AND DEVELOPMENT

MONTHLY REPORT
MONTH END
SEPTEMBER 2000

1 Executive Summary

The ALMA project continues to make progress toward readiness for the start of construction. One significant step was made at a Joint Receiver Design Group meeting in Cambridge England and a follow-up meeting in Tucson, Arizona. A complete top-level design for the Front-end subsystem was agreed to and baselined. This top-level design is now the basis for all of the detailed design work now under way and will lead to a Front-end Preliminary Design Review in February 2001.

A major advance in the receiver components area has been the successful demonstration of a 211-275 GHz mixer with 8 GHz IF bandwidth. By integrating an IF preamplifier with an SIS mixer, good performance was achieved over entire 4-12 GHz IF band.

Another area of major progress this month is the correlator. The first prototype card for the FIR filter has been fabricated and is undergoing tests. This card, which consists of surface mounted components, was assembled at the Tucson ALMA Lab using our new surface mount prototyping capability. This capability dramatically reduces the turnaround time and cost for prototype surface mount boards.

The initial design for the custom correlator chip is complete. Extensive testing of the computer model for this chip is underway prior to releasing the design for fabrication early next year. The computer model predicts the output of the chip for a large battery of test vectors to ensure proper logical and timing performance.

In anticipation of Japanese participation in ALMA, the ASAC has begun to study the scientific gains of possible enhancements to the baseline ALMA scope. The goal is to establish a set of priorities should the addition of the Japanese provide an opportunity to fund enhanced science capabilities.

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.

3 Meetings and Reports

3.1 Scheduled Meetings in Current Month

September 2000

- ALMA Photonics Meeting - September 01
- ALMA U.S. Division Head Teleconference - September 5, 11, 18, 25
  Minutes are distributed to all ALMA U.S. Division Heads via email
- 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
- ALG Face-to-Face Meeting - September 11
- ALMA US DH Face-to-Face Meeting - September 21
- ALMA Optics Workshop - September 25-29
  Various reports will be posted on the ALMA web site
- ALMA Test Interferometer Bi-Weekly Teleconferences
- ALMA/NSF Meeting - weekly teleconferences
- ALMA Lo/Rx Meeting - weekly teleconferences
- ALMA Imaging and Calibration Meeting - weekly teleconferences
- ALMA Executive Committee Meeting - weekly teleconferences

3.2 Planned Meetings for Next Month

October 2000

- ALMA Joint DH/TL Teleconference - October 2
- ALMA Joint Receiver Development Group Teleconference - October 5
- ASAC Teleconference - October 9
- ALMA Holography CDR - October 10
- ALMA Test Interferometer Planning Meeting - October 11
- ALMA LO Construction Planning Meeting - October 12

- ALMA SSR Meeting - October 12-13
- ALMA Coordination Committee Meeting - October 13
- ALMA Joint DH/TL Meeting Minutes - October 30
- ALMA Executive Committee Meeting - weekly teleconferences
- ALMA Test Interferometer Bi-Weekly Teleconferences
- ALMA/NSF Meeting - weekly teleconferences
- ALMA Lo/Rx Meeting - weekly teleconferences
- ALMA Imaging and Calibration Meeting - weekly teleconferences

3.3 ALMA Memos

The following ALMA memos were received this month:

324 Proposal for ALMA Front End Optics
W. Grammer, B. Shillue, L. D'Addario, J. Payne
323 Numbering of Drawings, Specifications and Similar Documents
L. D'Addario
322 Comparison of Meteorological Data at the Pampa La Bola and Llano de Chajnantor Sites
Seiichi Sakamoto, Kazuyuki Handa, Kotaro Kohno, Naomasa Nakai, Angel Otarola, Simon J. E. Radford, Bryan Butler, and Leonardo Bronfman

4 Technical Progress Reports

4.1 Antennas

During the month the antenna group continued monitoring the Vertex antenna contract. ALMA-US personnel were in the contractor's facility in Duisburg, Germany on 27-29 September. The contractor is working hard towards CDR on 15-16 November. The key design area still being worked by the contractor is the performance of the receiver cabin with respect to thermal deformation. An elevation buffer has been found that will be capable of absorbing the energy of the antenna driven at full speed into the stop without damaging the reflector. The use of a commercially available hexapod for the subreflector adjustment mechanism is being explored. Samples of the solar diffusive surface treatment for the reflector panels were supplied to NRAO so that they can be tested for diffusivity and resistive loss. Proposals for the transporter pickup points were provided so that NRAO can negotiate these with the ALMA-Euro antenna group.

Within the antenna group work continued on the optical pointing camera, the subreflector nutator, infrastructure preparations at the VLA site and updated versions of various of the antenna Interface Control Documents.

4.2 Frontend

Receiver Components

Tests continued on the 211-275 GHz mixer with integrated preamplifier for the 4-12 GHz IF band. We have now achieved good performance across the full RF band and across the full IF band. Work is now concentrating on repeatability of performance with different mixer chips in order to evaluate the production suitability of the design.

The first block for the 211-275 GHz sideband-separating, balanced mixers, fabricated in the Charlottesville shop, has been completed. All other components including bias boards and SIS chips are in hand, and assembly and first test is expected before the end of October. 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 was done on designing the configuration of the sideband-separating, balanced mixers using the wideband IF amplifiers.

Work continued on refining the data acquisition and processing software for automatic SIS mixer testing. The system can now use either a power meter for precision, well-calibrated measurements at low acquisition speed, or a simple square-law detector circuit for fast data acquisition, permitting optimization of controllable parameters and providing immediate feedback of relative mixer performance to the tester. This will be invaluable in optimizing performance of the sideband-separating, balanced mixers, for which there are 8 adjustable parameters.

NRAO engineers attended the ALMA SIS Working Group meeting which was held in conjunction with the Applied Superconductivity Conference in September. There seems to be a consensus that manufacturing the large numbers of good junctions required for ALMA is a production challenge which must be met with process refinements.

The mixer block for 650 GHz was delivered at the end of September. Some of the dimensional tolerances were not met, and the block was returned to the outside contractor for adjustment. Work is continuing on building up the 650 GHz test receiver optics.

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) was completed with collaborators at the Herzberg Institute in Canada and issued as ALMA Memo 316. All these waveguide components are being extensively modeled and optimized using Quickwave simulation software.

Further 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 modeling now in progress consists in matching SIS junctions to the structure and designing a suitable waveguide probe. If this can be done satisfactorily, then the design may be completed and fabricated.

The SIS mixer group wrote and submitted contributions for the Front End section of the new ALMA Project Book.

Front End Design

Following a recommendation at the JRDG meeting in Cambridge a working group was set up to produce an optical layout design for the ALMA receivers. The design documents produced by several groups were reviewed in the light of the clarification of the receiver requirements that resulted from the ASAC meeting held in Berkely. Of particular concern were two requirements 1) The inclusion of a cold load in the receiver dewar. The inclusion of this and the additional optics required for its implementation would have resulted in a complex receiver design that some members of the JRDG felt to be impractical. This requirement was dropped by the ASAC. 2) The polarization purity requirement. Although this requirement is still somewhat unclear there was sufficient understanding for the working group to proceed with the optics design.

At the conclusion of the five day meeting a clear layout for the dewar and optics was achieved. Further design work has been identified and when completed a comprehensive design document will be issued. This will include the geometry, performance and tolerances.

Collaboration between the US and the various European groups has continued and the various critical work packages as yet unassigned are being negotiated with different groups.

4.3 Local Oscillator System

LO Sub-System

The concept for the photonic transmitter for the Test Interferometer Holography System was further developed in preparation for the Holography Critical Design Review in October. The photonic transmitter will be tunable from 75-104 GHz and is intended to be used at 79 and 104 GHz for holography. Also, research was done on component laser systems for the Test Interferometer Laser Synthesizers. This included contacting vendors and gathering prices and specifications, and also contacting colleagues at other research facilities for recommendations and advice.

For the Test Interferometer, design work continued on the Gunn diode oscillator tuning and phase locking circuitry.

Measurements of the temperature sensitivity and long term phase drift of LO driver components and chains were completed and work was begun on a memo describing the results; this will be complementary to ALMA Memo 311 which describes short-term phase noise characteristics.

Initial work was performed on possible configurations of the LO driver components. In the laboratory test fixtures, the various components are interconnected with sections of coaxial cable and waveguide. In the production version, it is expected that there will be multiple active chips of different types within the same block (such as a final frequency

multiplier and power amplifier), and that blocks will butt against each other without cables or connectors. A preliminary analysis of the costs of configuring the LO driver system in various possible ways was performed, and this work will be pursued.

The development of fabrication techniques which are expected to lead to more-integrated frequency multiplier structures at the University of Virginia were continued. We expect that frequency multipliers made with the UVa techniques will be useful up to about 250 GHz.

Negotiations with the University of Michigan were begun in a three-way frequency multiplier effort which will include JPL. This collaboration is expected to provide a second source for mixer diodes (in addition to UVa) and quick-turnaround fabrication of MMIC structures for frequency multipliers above about 250 GHz.

A prototype prescaler board for the 2nd LO synthesizer was populated and testing is underway. Vendors for the 2nd LO YIG oscillators are being contacted. The design for the digital section of the Central Reference Generator was successfully implemented using the Xilinx XCV50 FPGA chip. Questions about jitter on the output clock frequencies are being looked at now as well as the output loading requirements.

An inexpensive, packaged, Fabry-Perot laser system to be used in the Low Frequency LO Reference fiber optic distribution system was indentified. If these work as well as advertised, they would be less expensive than the DFB laser system originally conceived.

4.4 Backend Subsystem

The new Gore coax assemblies installed on the 8510C vector network analyzer made a huge improvement by removing all frequency glitches and instabilities compared to the old. Analysis of the vector network analyzer data on the sample General Microwave 1.5-4.0 GHz digital attenuator was completed; stability of magnitude and phase vs. temperature and bias voltage is excellent.

A new specification for the downconverter pin diode attenuators was then generated and an RFQ was issued. Analysis of the AD7731 sigma delta digitizer for the total power detector of the Downconverter is underway and an evaluation board for a 16 bit SAR digitizer will be acquired.

The layout of the clock generator PC board for the high speed data transmission system was submitted for file check, design rule check and price quote. After one iteration, the design passed these checks and a Purchase Order was issued. Parts for the board have started arriving and population and testing should occur next month.

4.5 Correlator

The first FIR filter printed circuit board was populated with components in Tucson. Tests will begin in mid-October, initially without the test fixture. There have been

problems with procuring many standard parts, with many components either having long lead times or being on indefinite allocation.

The Long Term Accumulator Card, Station Card, and FIR Filter/Station test card layouts were completed and the designs were sent out for printed circuit card fabrication. Testing of these cards will probably begin in November. Work continued on the design of the Correlator Card, which is substantially done but awaits freezing of the chip design. A trial layout of the card design as it exists was done, and proved not too difficult, considering that the card will have over 6,000 nets, 73 240-pin chips, and over 1000 other components.

Work was begun on writing software for the Infineon microprocessor which will be used on the correlator control cards.

The custom correlator chip initial design is complete. Work now consists of submitting numerous test vectors to the chip simulation software and verification that the design will work. This is expected to continue until near the end of 2000, with simulation work proceeding both at the chip designer's site and in Charlottesville.

4.6 Computing

Administratively, in September, two new full-time staff members started in the ALMA software group, one at NRAO/Tucson (position transferred from Tucson operations), and one at ESO. Planning the optical telescope tests on the 12m antenna continued with University of Arizona staff. The only remaining issue is the assumption of liability by the NRAO during the tests. A Construction Project Book chapter was delivered to Systems Engineering.

The High Level Analysis and Science Software Requirements groups continued their work, principally by elaborating Use Cases related to observing modes, to be discussed at the October meeting in Berkeley.

In Software Engineering, a decision was taken to adopt the ESO Software Problem Reporting (SPR) system for ALMA Phase 1. The initial software Change Control Board will consist of the NRAO Division Head and European Team Leader. A standard software document template was circulated for comment.

For ALMA Common Software, work towards release 0.0 continued. This included release preparation and testing, and a VxWorks port. Work towards the optical telescope tests continued. This included porting the antenna motion API to the VME 2604 processor, including support of several required hardware boards (IRIG, parallel I/O, and D/A). Socorro systems that will be carried to Kitt Peak for the tests were installed with the required software.

The Control Software group prepared for the Holography CDR. This included preparation of several draft ICD's and additional design documentation. The test interferometer design and requirements document were significantly revised and reviewed internally at a week-long design meeting. An initial set of high-level

("observer") commands was prepared for the requirements document. A new 3U CAN board was designed, and firmware and LabView panels were created for the Helium compressor system. An initial mount control server was released in support of the 12m tests. A pointing model was provided to the antenna vendors, and an update to the Antenna/M&C ICD was released.

For Telescope Calibration, a draft data format was proposed. This will form the basis of an ICD between the Control Software and the Telescope Calibration software. A reuse analysis of the IRAM CLIC package was written for the Holography review.

In October, the Science Software Requirements and High Level Analysis groups will hold a meeting in Berkeley. A CDR for systems required for Holography will be held. ACS version 0.0 will be released.

4.7 Systems Engineering

The main activity this month was preparation for the ALMA Holography CDR, to take place early in October; all aspects were covered, including the photonic transmitter design, the receiver design, justification for precise frequencies of holographic measurements, etc.. Documentation, including ICDs, were prepared as background material for the meeting. The documents can be found from:
http://www.tuc.nrao.edu/~demerson/holocdr/ .

The Project Book, for which the joint US-European systems group is responsible, is becoming more complete, although material in some areas is coming in from the specialist divisions more slowly than had been anticipated.

Weekly transatlantic teleconferences are now being held between the US and the European systems groups. A variety of issues is being covered, including issues of standardization of packaging of electronic modules, power supplies, and documentation. Good progress is being made, although much work in reconciling US and European standards remains to be covered in this area.

Members of the Systems Group participated in a number of ALMA meetings on a variety of topics; in particular, in the one-week workshop on ALMA Receiver Optics held in Tucson this month, and the ASAC meeting held in Berkeley. At least one member of the systems group visited the Rutherford-Appleton laboratories, and also the Cavendish laboratory at Cambridge University, during the period covered by this report.

4.8 Imaging and Calibration

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

The imaging and calibration group held several phone meetings during September, 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 continued during September. Steve Heddle in the UK continued to progress on the imaging simulation, producing 3km Array snapshots and 4 hour tracks for simulations of objects in the image library using both the Kogan double ring and zoom spiral configurations (http://www.heddle97.freeserve.co.uk/ALMA/CLEANIND.HTM). Min Yun reported to the ASAC on the progress to date at their face-to-face meeting in Berkeley on 9-10 September. During September, Min took up a position as Assistant Professor at the University of Massachusetts. He plans to continue his ALMA activities as he can. Kogan remains as an active member of the configuration group.

Butler worked on finalizing the memo on the location of the compact configuration, which will be issued soon.

B. Atacama Compact Array

Definition of and imaging test for the Atacama Compact Array (ACA) continued with several reports issued, notably the ALMA Scientific Advisory Committee (ASAC) endorsement of the ACA as a desired component of the enhanced ALMA. During September, Welch produced a memo for the ASAC on the number and size of the antennas. He concluded that for the compact array to contribute a point source sensitivity matching that of the more closely spaced 12m antennas, the necessary number of small antennas is approximately (12/D_C)$\times$6, where D_C is the diameter of the compact array antenna. A 6m antenna should provide good imaging characteristics and suitable calibration sensitivity. The ASAC concluded that 'Based on studies by Guilloteau, Welch, and Morita, there is general agreement on the range of antenna number (10-16) and sizes (6-8 m) for the ACA. Generally, smaller diameters are better for imaging, as long as the minimum spacing is set by antenna size, while larger antennas are better for calibration.' They called for a study of how minimum separation depends on dish size for dishes mounted on the standard 12-m mount; a study of the effects of dish size, between 6 and 8-m dishes, and of the number and layout of dishes on imaging of several of the standard test images. The imaging study should include the effects of errors due to noise, calibration, and pointing and be done at representative frequencies where these errors have different relative sizes.

Jaap Baars intitiated the first of these studies, and produced a draft recommendation by month's end. Wootten provided a memo on the need for nutating subreflectors in the compact array, concluding that a nutator on at least one antenna should be planned for high frequency operation of the array. Morita and Yun pursued their studies of the imaging characteristics of the array. Morita has been using the SDE package for his simulations, while Yun has used AIPS and investigated the use of AIPS++.

C. Site

Wootten delivered a report to the ASAC on the monitoring of the site. Visits by ASAC members and others resulted in reports from CBI observers on their experiences in making observations from the site. Bronfman reported that the weather has been poor throughout the year in Chile in general, though the site monitoring data suggest it remains

better than during the El Nino year. The CBI observers report 67% usable nights during non-summer months, but had some access problems owing to snow which would not have been a problem at Pampa La Bola.

Radford initiated a detailed study of contemporaneous tipping radiometer data at the two sites to determine how the transparency differed between the sites. Sakamoto, Radford, Butler and others had found in ALMA Memo No. 322 issued last month some suggestions of more variable wind direction at the lower Pampa La Bola site, so Butler initiated a study of contemporaneous phase comparisons from the site testing interferometers located on both sites.

Radford updated Project Book Chapter 14 (Site Characterization) and updated reduction of site data through 24 August.

Plans for visiting prospective pad locations during upcoming visits to the site were discussed. Deployment of the Inmarsat M4 terminal at Chajnantor will be delayed until December at the earliest owing to equipment failure.

II. Calibration

A. Interferometer/Antenna Amplitude Calibration

Mangum presented his investigation of amplitude calibration schemes to the ASAC. Welch described the two-load chopping scheme being investigated by the MDC at BIMA, along with other ideas in a recent memo by Plambeck. Guilloteau compared relative merits of several schemes. Emerson presented a scheme for bandpass calibration which is planned for implementation. The ASAC endorsed continued investigation of the two-load scheme, along with development of the use of a semitransparent vane and the use of coherent signals as described by Emerson. Mangum initiated study of the semitransparent vane and of implementation issues for the ALMA adaptation of the BIMA prime focus amplitude calibration system.

Mangum visited Hat Creek to get a first-hand look at the BIMA apex amplitude calibration system. Discussions with Jack Welch regarding the implementation of this system in the ALMA antennas indicated that we should have no problem making the slight modifications needed to make them fit in the apex hole of the Vertex antenna. Simon Radford continues work on the ALMA nutator design incorporating this system.

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

III. Science

A. ALMA studies, including the ASAC

At an NRAO-wide retreat in Socorro, members of the Imaging and Calibration Group got to meet face-to-face with each other, with others in the observatory and with other members of the project, discussing a wide range of subjects. Several presentations were

made at the retreat. Wootten discussed use of ALMA antennas as single antenna telescopes during early phases of the project.

Cleanup work continued on the volume summarizing ALMA Science from the meeting last October.

Plans for the face to face ASAC meeting in Berkeley, including the agenda and reading material were finalized by Wootten. The meeting occurred with good progress and by month's end the ASAC report was reaching its final form. Wootten also attended the correlator meeting held just after the ASAC meeting and reported on that meeting in the ALMA 'virtual hallway'. He presented a report and wrote a section on the ALMA correlator on the 'baseline ALMA correlator' for the ASAC report.

Preparations were made for the face-to-face ALMA SSR meeting in Berkeley during mid-October. Rough drafts of use case observing modes will be discussed there.

B. Imaging and Calibration

Plans for next month: Mangum and new SSR appointee Steve Myers will attend the ALMA SSR meeting in Berkeley.

The ASAC report will be disseminated to the project.

Configuration work will continue, with a focus on finishing a set of the simulations, extending them to more compact arrays and distilling the results into a recommendation on array design. A phone meeting of the configuration group is planned for October. Hopefully, with the impending release of AIPS++ mosaicing will become a part of the simulations soon.

Work also continues on the characterization of the ACA.