MILLIMETER ARRAY/ALMA-US
DESIGN AND DEVELOPMENT

BIMONTHLY REPORT
JULY-AUGUST 2001

1 Executive Summary

VertexRSI continues to report that they are on schedule for a 23 April 2002 handover of the prototype antenna. Progress is being made in all key areas for delivery of antenna components beginning in late December 2001 at the VLA site. All major components are either manufactured or being manufactured at this time with a schedule delivery consistent with the handover date. The antenna foundation has been completed and is ready for the start of contractor activities at the VLA test site, which will start near the end of the year.

The European prototype antenna is still delayed due to the contract dispute between ESO and the antenna contractor, EIE. Measures are being taken to resolve this contract dispute. ESO is expecting a proposal from EIE in September that will be considered. A completion date for the antenna is unknown until this matter is resolved.

Measurements were completed on the prototype Band 6 elemental mixer with integrated preamplifier. This prototype has the widest IF band (4-12 GHz) of any SIS mixer developed so far. A paper describing this work was presented at the IEEE International Microwave Symposium in Phoenix, AZ.

The design of the custom correlator chip, designated ALMA-1, was completed by the vendor, Innotech Systems, and verified by simulations performed there and by NRAO engineers. The printed circuit board that will host this chip has already been designed and is in fabrication. Fabrication and testing of the correlator board cannot be completed until prototype quantities of the correlator chip are available next year.

The Expanded ALMA Executive Committee (EAEC) met in Charlottesville in August to respond to the EACC charge to recommend a plan and division of effort for a Tripartite project at the EACC meeting scheduled for the end of October. Significant progress was made reorganizing the detailed tasks originally developed for the Bilateral project into W*ork Packages* that are more suitable for the Tripartite project. The effort of producing an acceptable division of these work packages will continue at the planned EAEC meeting in September at the Rutherford Appleton Labs in Oxford, England.

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 66.3.

2.3 Progress Against Project Milestones

While retaining and managing to the baseline bilateral work breakdown structure, significant effort has been expended developing a modified work plan that incorporates the major program changes being discussed as part of a potential Japanese entry into the project. These changes include the addition of four additional receiver bands, the Compact Array and the Second Generation Correlator. As a result, an update to the graphical representation of the baseline bilateral WBS has not been completed and a project Gantt chart is not included for this period.

Significant milestones from the baseline bilateral work breakdown structure that were completed during this period include:

- Completion of the first antenna CFRP BUS segment
- Completion of the antenna foundation (ahead of schedule)
- Completion of a prototype LO RF synthesizer circuit board
- Completion of the design of the correlator chip

Delivery of a completed backend bench prototype, originally scheduled for completion this period, is now scheduled for completion in December, well ahead of its need date. The delay is due to staff shortages earlier this year.

3 Meetings And Memos

3.1 Meetings Held During July and August 2001

ALMA US DH Teleconference - July 2, 9, 16, 23
Tri-lateral Project Teleconference - July 30
SSR Face-to-Face Meeting - July 16-17 - Berkeley, CA
ALMA US Division Head Teleconferences - July 02, 09, 30
ALMA Tri-Project DH Teleconference - Jul 30
Canadian Participation Meeting - August 16 - 17 - Victoria, Canada
EAEC Face-to-Face Meeting - August 27 - 29, Charlottesville, VA
ALMA US Division Head Teleconferences - August 06, 13, 20
Correlator Meeting - August 04-07 - Tokyo, Japan
ASAC Teleconferences
EAEC Teleconferences
AEC/SE Teleconferences
ALMA Systems Group Weekly Teleconferences
ALMA Imaging & Calibration Teleconferences

3.2 Planned Meetings in September and October 2001

ALMA Tri-Project DH Teleconference - Sept 04
ALMA US DH Teleconferences - September 17
ASAC Face-to-Face - September 9 - 13 - Chile
ALMA Joint Software Meeting - September 26 - 27 - RAL
ALMA Front End Meeting - September 26 - 27 - RAL
ALMA Photonics Meeting - September 27 - RAL
EAEC Face-to-Face - September 28 - 29 - Cambridge, England
ASAC Teleconferences
EAEC Teleconferences
AEC/SE Teleconferences
ALMA Systems Group Weekly Teleconferences
ALMA Imaging & Calibration Teleconferences
EACC Meeting October 30-31 – Washington, DC

3.3 ALMA Technical Memos Distributed in July and August 2001

379	SUMMER CLIMATE OVER CHAJNANTOR	Ricardo Bustos
381	Elements for E-Plane Split-Block Waveguide Circuits	A. R. Kerr
382	MM-VLBI with ALMA	Melvyn Wright, Geoff Bower, Don Backer, Alan Whitney
383	A Simple Technique for Disciplining Independent Demultiplexers	Marc Torres and Olivier Gentaz

384	Atmospheric Transparency at Chajnantor and Pampa la Bola	Simon J. E. Radford, Bryan J. Butler, Seiichi Sakamoto and Kotaro Kohno
385	Orthogonal Functions for Phase Switching and a Correction to ALMA Memo 287	Larry R. D'Addario
386	ALMA+ACA Simulation Tool	J. Pety (IRAM), F. Gueth (IRAM), S. Guilloteau (IRAM)
387	ALMA+ACA Simulation Results	J. Pety (IRAM), F. Gueth (IRAM), S. Guilloteau (IRAM)
388	Degradation of Sensitivity Resulting from Bandpass Slope	A. R. Thompson
389	Radio Interferometer Array Point Spread Functions I. Theory and Statistics	David Woody
390	Radio Interferometer Array Point Spread Functions II. Evaluation and Optimization	David Woody
391	A Square Wave Phase-Switching Scheme for a Large Number of Antennas	A.R.Thompson and L. R. D'Addario

The full catalog of the ALMA Memo Series can be found at the ALMA web site at http://www.alma.nrao.edu/memos/.

4 Technical Progress Reports

4.1 Antennas

VertexRSI continues to report that they are on schedule for a 23 April 2002 handover of the prototype antenna. Progress is being made in all key areas for delivery of antenna components beginning in late December 2001 at the VLA site. All major components are either manufactured or being manufactured at this time with a schedule delivery consistent with the handover date.

The prototype BUS sector is completed and can be seen in figure 4.1.1. This BUS section is being prepared with two panels mounted on the structure and a mounting fixture. This structure will then be ready for detailed thermal and mechanical testing to verify the design and fabrication of this CFRP structure. The thermal testing will occur at the beginning of September in a special test chamber in Munich and then the mechanical testing will occur at Vertex Antennentechnik (VA) in Duisburg. This is the key technology-testing phase of the contract. Production of the BUS sectors is being prepared in parallel with testing in order to meet the scheduled delivery date. Minor changes to the BUS based on testing can be accommodated in the BUS production if necessary.

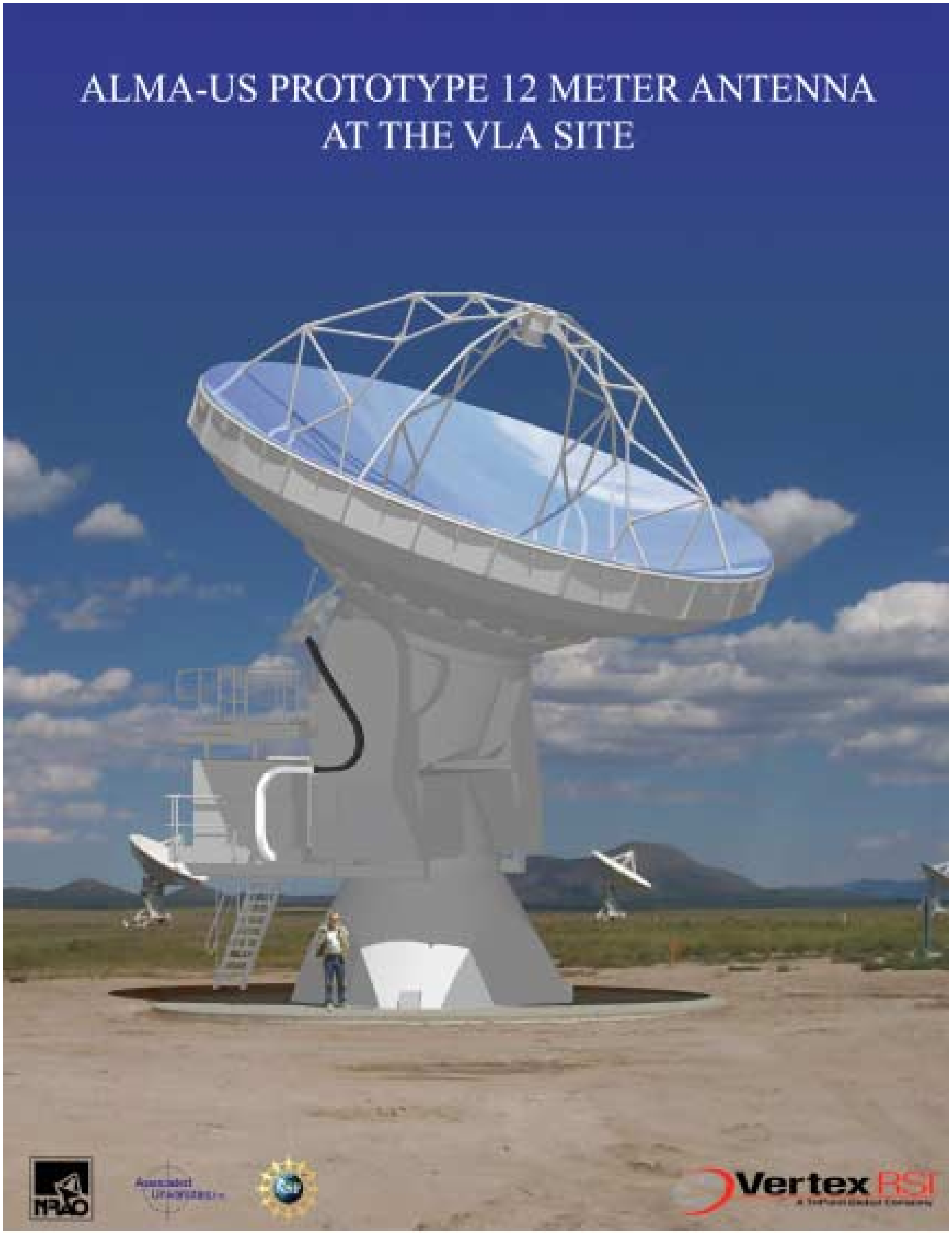
The foundation contractor has completed the antenna foundation to specification at the VLA site as seen in Figure 4.1.2. The foundation is now ready for the VertexRSI antenna delivery.

Figure 4.1.2. *Completed foundation for VertexRSI antenna at the VLA site.*

Several antenna components have arrived at VA such as the drive motors, amplifiers, servo equipment cabinet that is fully outfitted, UPS system and auxiliary equipment rack and receiver installation forklift. VA has equipped their single axis servo test stand with antenna drive motors and they are preparing to do a single axis servo testing. The azimuth bearing is completed and has been shipped to the steel fabricator. The BUS pattern was delivered last month to the CFRP BUS fabricator.

The European prototype antenna is still delayed due to the contract dispute between ESO and the antenna contractor, EIE. Measures are being taken to resolve this contract dispute. ESO is expecting a proposal from EIE in September that will be considered. A completion date for the antenna is unknown until this matter is resolved.

A rendering of the VertexRSI antenna on the VLA site was generated by NRAO and is shown below.



4.2 Frontend

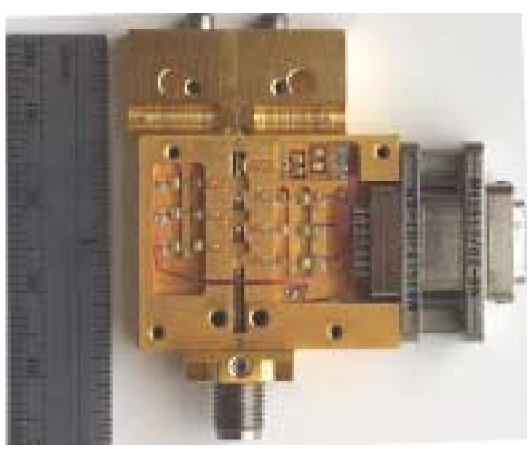
The results of measurements performed on the prototype Band 6 elemental mixer with integrated preamplifier were published on the web as ALMA Memo 378. This prototype has the widest IF band (4-12 GHz) of any SIS mixer developed so far. A paper describing this work was presented at the IEEE International Microwave Symposium in Phoenix, AZ.

The results of design, simulation, and measurement work for E-plane split-block waveguide elements which can be used as building blocks in complex circuits were published as ALMA Memo 381. The circuit elements include a compact H-plane bend, a short E-plane bend, a matched E-plane Y-junction, and a broadband transducer from full-height waveguide to quartz suspended stripline. These elements may be useful in combination with other newly-developed elements such as waveguide hybrids and T-junctions.

SIS mixer design

Two designs with shop drawings were completed for the Band 6 balanced, sideband-separating SIS mixer with integrated preamplifiers. One design uses the single-chip Band 6 mixers, and the other uses waveguide hybrid elements and single mixer chips. One of these assemblies, depending on test results, is expected to be very close to the final design of the mixers which will go into the Band 6 cartridges.

In order to use the integrated IF amplifier to achieve wideband performance with a balanced SIS mixer, a new mixer-amplifier interface is required. The design for the interface and the necessary slightly modified amplifier were completed, and construction of the amplifiers and mixer blocks was started. During September-October, we anticipate testing and verifying this interface in the laboratory. Once this interface is in final form, it will be used with the balanced, sideband-separating mixer, which consists of two identical balanced mixers. This will be the last stage of development of the Band 6 mixer.



The prototype wideband Band 6 SIS mixer with integrated preamplifier. The SIS mixer is at the top, with signal input in waveguide perpendicular to the plane of the paper. Most of the volume is taken by the 3-stage preamplifier, which is at the bottom. Output is on a coaxial connector.

We have been assisting ALMA front end designers in Europe to interface our wideband IF amplifier to their mixer designs. We received a report that Andrey Baryshev at SRON was largely successful in his first attempt to achieve wideband, low-noise performance for Band 9.

SIS mixer instrumentation and measurement

Measurement of SIS mixers in the laboratory requires test receivers. In order to understand and more accurately calibrate the test receivers, we have undertaken a series of development efforts which include optics and LO injection techniques. This has included design, simulation, and measurement of lenses, vacuum windows, feed horns, IR filters, mirrors, and overmoded waveguide. Several new designs were produced and tested. The use of overmoded waveguide for LO injection was extensively modeled and a comparison of the results of the simulation program Quickwave with a newly-available simulation package called CST was made.

Work continued on outfitting a second 4K dewar for SIS mixer testing. This work includes improving the control and measurement instrumentation. New control and data acquisition software was written and deployed in the dewar which is use at present.

The total power stability of SIS mixer receivers is an important factor in the single-dish continuum radiometry required of at least some ALMA receivers. Comparison of this stability with the stability of HFET amplifier receivers is an important factor in the selection of the appropriate technology for the Band 3 cartridges. We have undertaken a series of laboratory measurements to characterize the stability of the Band 6 SIS mixer with the wideband integrated IF amplifier.

One factor known to be important to the total power stability of SIS mixer receivers is the temperature stability of the cryogenic refrigeration system. A series of measurements of the laboratory test dewar, which employs a 2-stage GM refrigerator followed by a J-T 4K stage, showed the temperature stability of the 4K stage to be a few mK, with no dependence on the 0.7K 1-second cycling of the GM refrigerator 20K stage.

The first attempts to measure the SIS mixer receiver total power stability revealed many instabilities which were traced to component characteristics, power supplies, component placement, and grounding problems; eliminating these effects required much effort and is an object lesson for the ALMA receivers. Measurements were made with the objective of characterizing the total power stability of all the receiver elements prior to attempting to measure the whole receiver stability. The only spurious noise now detected is at 60, 120, 180, and 240 Hz—harmonics of the power line frequency—which are notoriously difficult to eliminate completely.

LO Multipliers

Three wafers containing the diode structures for an 80 to 240 GHz frequency tripler were made by the University of Virginia. The first two wafers were faulty, but the diodes in the third wafer appeared to be good. However, instead of the expected 10 mW of power output with 50 mW of power input, only about 0.5 mW was obtained. It is not clear whether there is a fault in the diode contacts (too-large ohmic losses?) or a problem with the fabrication of the remainder of the circuit. The circuit appears to be tuned correctly, and input power is absorbed. This is being investigated further.

At the University of Michigan, the first attempt to make diodes like those previously made by the University of Virginia for use in a 55 to 110 GHz frequency doubler resulted in excessive undercutting of the anode. The masks have been modified to match the University of Michigan process more closely, and another wafer will be fabricated for testing in this proven design. Workers at the University of Michigan are also developing techniques for wafer thinning which can be used with advanced high-frequency multiplier designs.

4.3 Backend and Local Oscillator Subsystem

The primary task for the LO and BE systems for the remainder of 2001 is to accomplish a bench integration. This will join together the major modules of these two systems in their rough prototype form. Computer control of these modules using early versions of the Test Interferometer software will be exercised.

Backend System

The main components under development in the US are the Downconverter module and the digital Data Transmission System.

The ALMA Downconverter takes the 4 to12 GHz IF signal from the Front End Assembly and converts it to four 2 to 4 GHz output signals. Component evaluation for the Downconverter is nearly complete and assembly of the bench prototype system will start shortly. An integrated design of the 2nd IF sub-assembly is underway with the goal of incorporating it into the bench system later this year.

The Data Transmission System is used to carry the digitized IF signal from the ALMA antennas to the Central Electronics Building and is composed of twelve 10 Gb/s digital links. This system is being prototyped for use on the Test Interferometer.

The prototype of the digital transmitter (Mux) printed circuit card has been fabricated, populated and is being tested. This card can support three 10 Gb/s links, but only one link is populated at this time. The main card makes use of daughter cards containing the 10Gb/s Mux chips. The first version of a daughter card has been successfully fabricated and is being tested on the main card. The placement of surface mount components on both of these cards was done in conjunction with the ALMA staff in Tucson using their reflow oven.

The layout for the main and daughter digital cards for the link digital receiver (Demux) is underway.

The interface between the Test Interferometer digitizers and the ALMA data link is accomplished by the Uprate Converter. The design and layout of the main printed circuit board was completed and submitted for fabrication.

Local Oscillator

The LO provides the coherent reference signals needed at the ALMA antennas to do interferometry. The main components under development in the US are the high frequency (~100 GHz) dual laser photonic reference distribution system and the low frequency (~10 GHz) reference and timing distribution system. Local Oscillator components closely associated with the Front End dewar are considered part of the FE System.

A printed circuit board containing a microprocessor, voltage regulaors and phase lock loop components for the 6 to14 GHz 2nd LO synthesizer was fabricated, populated and tested. This board was connected to the microwave components of the synthesizer and the full module design is being tested.

A prototype of the Fine Tuning Synthesizer (FTS) has been completed. This device provides an offset frequency for the antenna LO synthesizers of about 30 MHz and can be controlled with micro-Hertz accuracy. The firmware embedded within the device will need to be refined, and the interface to the monitor/control system needs further development.

A 75-110 GHz photonic photo mixer was developed at the RAL and shipped to the Tucson Photonics group. There is undergoing tests using an 86 GHz radiometer. This photo mixer will be used in the dual laser LO distribution system for the Test Interferometer

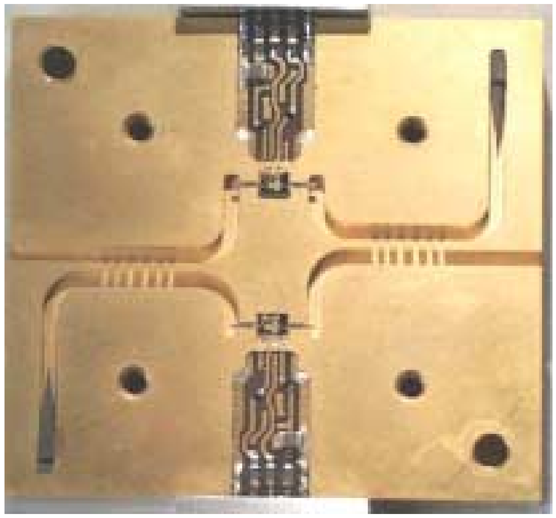
The results of measurements of phase and amplitude noise of the LO drivers were published on the web as ALMA Memo 335. A paper on the results was presented at the IEEE International Microwave Symposium in Phoenix, AZ.

LO Drivers

In order to provide enough power to drive the high frequency LO multipliers, in some cases it may be necessary to combine the power from several final-stage MMIC amplifier chips. A prototype power-combining balanced amplifier with excellent impedance match was built and tested using the waveguide-hybrid circuit elements described earlier. Using MMIC amplifier chips useful over the frequency range 103-109 GHz, power combining efficiency greater than 80% and power output greater than 200 mW was achieved.

In order to reduce LO driver fabrication costs, it is desirable to integrate components into single blocks to the greatest extent possible, while retaining simplicity of design. A diode tripler chip with output in the range 75-110 GHz was supplied to us by JPL and tested in an NRAO-designed block. The chip gives results in this package comparable to those of the on-wafer measurements.

When combined with two Agilent 5040 commercial MMIC chips (one configured as a doubler and the other as an amplifier), this produced a X6 multiplier with 1-2 mW output over the Band 3 frequency range of 96-104 GHz. Setting the output level by controlling amplifier bias was successfully demonstrated. A block will be designed which incorporates all three chips; then one needs only the YIG-tuned oscillator on one end and the power amplifiers on the other in order to generate sufficient LO power. A final element to be incorporated is a 75-110 mixer so that the phase lock loop can be closed; this may also be integrated with the X6 multiplier.



The power-combining balanced 96-104 GHz amplifier. Input and output are via waveguide at left and right. PC boards supplying bias current are at top and bottom. The waveguide hybrids are the hatched structures. The MMIC chips are just above and below the center of the block.

A new compact printed circuit board layout was completed for the Phase Lock Loop board which controls the YIG-tuned oscillator; it is in fabrication.

The LO test apparatus was tested with a standard CAN bus interface, and the YIG-tuned oscillator frequency was successfully set with LabView software. It is planned to transfer all control functions for the LO drivers to CAN bus control so that the software will look more like the software to be used in the field.

4.4 Correlator

A report on the functioning of the FIR Filter Board as a digital filter was completed and posted on the web under the correlator section of ALMA Development.

Custom Correlator Chip ALMA-1

The design of the custom correlator chip, designated ALMA-1, was completed by the vendor, Innotech Systems, and verified by simulations performed there and by NRAO engineers. A purchase requisition for fabrication of the first prototype chips was submitted.

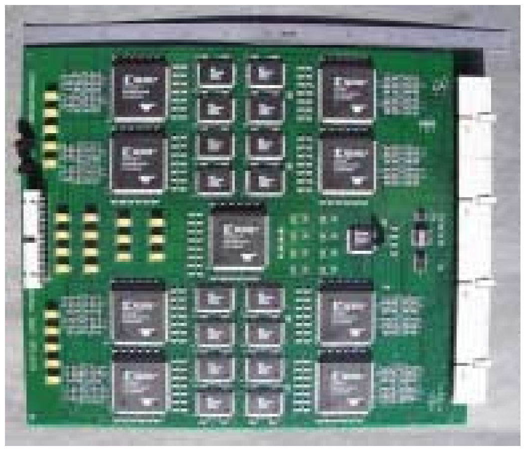
Correlator Board

The design of the Correlator Board was completed; this had been waiting for completion of the design of the correlator chip. A prototype board is now in fabrication, although completion will require the correlator chip fabrication to be completed.

FIR Filter Board

Initial testing of the FIR filter board was successfully completed, including its functioning in low-pass, high-pass, and bandpass filter modes. The board was tested with both 3-bit and 4-bit simulated samples, and there seems to be little difference in performance. A scheme of using tap weight offsets to reduce the number of toggling gates, and thus the power consumption, was tested and resulted in a 20% reduction in power with no difference in performance; more work needs to be done in this area.

Station Card



The prototype Station Card.

Initial testing of the Station Card was performed with memory chips which had only one-fourth of the desired capacity, due to unavailability of the desired chips. An order of memory chips with the full design capacity was received, and the prototype board was sent to Tucson to have the older chips replaced with the new ones.

Long Term Accumulator Card

Operation of the LTA was verified with pseudo-random input sums up to a clock speed of 140 MHz, which is well above the required operating speed of 125 MHz. The first level of control logic required to control the allocation of correlator output bandwidth among multiple sub-arrays has been written and verified. The specification for the LTA was extensively revised.

Adder Tree/FPDP Card

The Adder Tree/Front Panel Data Port card is intended to provide the last stages of accumulation and an interface to the post-correlation processor via a standard FPDP interface. Design of this card was begun.

Rack/Motherboard/Paddleboard

Work was begun on the integration of the various correlator printed circuit boards into a functioning whole. This involves design of an interface board to the digital IF receiving electronics (a "Paddleboard), the backplane of the chassis which will hold station cards and correlator cards (the "Motherboard"), and rack layout and wiring. Preliminary work was started in these areas.

4.5 Computing

The tripartite computing division heads and team leaders recommended to senior project management a division of software effort for Phase 2, including likely project scope enhancements.

The Science Software Requirements committee requirements document had its final review (ALMA-SW-0011). An ALMA memo (#367) on operational issues was produced. The requirements on the post-processing system and pipeline are in late draft form. A test of the suitability of AIPS++ for ALMA has started. Results are expected in late Spring 2002. The committee met face to face in Berkeley.

The high-level analysis group released their draft of the analysis document for final review. The draft is available on the web.

The software engineering group in response to comments issued revised C and C++ coding standards. The software change control board met in July to discuss accumulate software problem reports.

Work towards more detailed requirements and an eventual prototype proposal preparation tool were started.

A major (1.0) release of the ALMA Common Software was prepared for release in September. This release will have considerably improved functionality (e.g., an object explorer), and improved documentation and installation procedures.

A release (0.1) of the test interferometer control software was made. This release contains various device drivers, time related commands, monitor data collecting, and some high level commands available from the Python scripting language, and other miscellaneous features. A test plan for monitor and control tests at Vertex in October and January was prepared. Code was written and updated for some embedded processors (helium compressor, optical telescope camera). Work on a nutator simulator started. CORBA/IDL interfaces for the Vertex ACU and an update to the higher level mount interface were produced. Production testing of the AMBSI1 board was undertaken.

A simulator for the test correlator has been implemented, although more functionality and integration with the control software is needed. Interface components for a prototype correlator long term accumulator computer interface were selected.

In the telescope calibration area, the data format for the test interferometer was reviewed and posted on the web. The CLIC holography software was updated for knowledge of the Vertex panels, and Fresnel terms and first order non-Fresnel terms were included.

4.6 Systems Engineering

Planning for the Test Interferometer operation included reviewing specifications for the weather station instruments, refining refraction calculations, preparing millimeter wavelength source lists suitable for the TI, and preparing lists of optical objects suitable for the TI optical pointing telescope.

ALMA system phase noise budgets were evaluated and timing and synchronization specifications for phase switching we reviewed. In the coming weeks renewed effort will be placed on defining interfaces between modules and between subsystems.

4.7 Imaging and Calibration

Sakamoto has provided a rendering of ALMA plus the ACA which is shown below.

Effort during this period was devoted toward simulating the performance of ALMA operating as 64 elements interferometrically and total power as compared with ALMA operating in this fashion but with the addition of the Atacama Compact Array of twelve 7m antennas. Wootten wrote an ACA Project Book Chapter to define assumptions. Nearly one thousand simulated images were produced. The IRAM group produced uv data corrupted by phase errors simulating pointing errors and the passage of a phase screen over the site, using a CLEAN algorithm. At NRAO, Holdaway used a maximum entropy (MEM) algorithm on the same data to show that the simulated results did not depend on the algorithm used to form the images. Holdaway also simulated the effects of antenna surface errors on the data. Morita included the effects of noise in his MEM-based simulations. Guilloteau summarized the results of these simulations:

- Imaging by ALMA+SD alone will fail on some images
- ALMA+SD+ACA brings robustness to imaging with respect to image type, pointing errors, and primary beam errors, independent of imaging algorithm.
- Without the ACA, ALMA+SD can deliver image fidelities of 10-20 on some typical images, while ACA+ALMA+SD can deliver image fidelities of 30-60 on these images.
- Robust and simple imaging techniques for inclusion of ACA data exist; the ACA does not markedly increase computing time for array images
- An ACA model with 12 7m antennas and 4 12m antennas is sufficient
- The ACA brings insurance on the quality of the result
- Calibration of the ACA is feasible
- Direct effect of anomalous refraction is secondary to that of the phase screen. Anomalous refraction may cause the biggest effects through systematic corruption of single dish pointing on the 12m antennas
- Observation of a 'guard band' of fields brings improvement in uncrowded fields
- The ACA alone provides a fairly good high frequency array.

The final step in this process, scientific evaluation of the simulated images, continues.

The report from the Calibration PDR, held at the end of June, was drafted. Action items include:

- Receiver calibration needs engineering realization. Materials need to be identified for vane calibration and incorporated into a working system. Dual load system tests should address standing waves and frequency dependence of the system.
- Calibration Group should be formed and design should be iterated among its members. Prototype receivers must be built to push the system toward a final design.
- Characterization of standing wave patterns on the prototype antennas should be performed and assessed
- The WVR and fast switching schemes need further work. WVR schemes are not in production mode operation at 22 GHz. The combination of these techniques and rules for implementation are ill-defined.
- Anomalous refaction on the site needs characterization, perhaps with ASTE

Progress on the configuration was discussed during a telecon. Conway continues to iterate the final plan, to be discussed in a September telecon. Approval at the CDR should occur by the end of the year.

Radford revised Project Book Chapter 14 and circulated the new draft. Radford also received radiosonde equipment from Chile and dispatched it to the manufacturing Vaisala, for upgrade.

MILLIMETER ARRAY/ALMA-US
PROJECT STAFFING

AS OF AUGUST 2001

WBS Task Name	Number Of Persons Participating in Activity*	Full-time Equivalent Employees
Administration	12	7.4
Site Development	1	0.0
Antennas	5	2.5
Front-End	27	22.3
Backend & LO	14	13.8
Correlator	5	4.0
Computing	9	8.5
System Integration	5	4.8
Calibration	3	3.0
TOTAL:	81.0	66.3

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