THE ALMA TEST INTERFEROMETER (TI)

Purpose, Scope and Goals

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1. Introduction

When the Atacama Desert was chosen for the site of the MMA, it was decided at NRAO to build and test a prototype array element before going into the series production of the 40 or more antennas. In the context of the larger ALMA project with Europe providing a contribution comparable to that of the US, agreement has been reached to acquire two prototype antennas, one each procured and financed by NRAO and by ESO. This has the obvious advantage of putting industrial competition into the prototype phase of the project. It has also been decided to bring both antennas to the site of the VLA for the test program. Thus it will now be possible to combine the two prototype antennas into an interferometer, thereby significantly expanding the range of tests which can be undertaken, including the tests of prototype electronics for the final array.

The first priority of these activities is the thorough test of the antennas for their adherence to the specifications. The quantitative data on the antenna characteristics and behavior will enable one of the two prototypes to be selected for the eventual fabrication of up to 64 production antennas. The antennas will be subjected to a series of measurements, both as single dish antennas and connected together as an interferometer, the Test Interferometer (TI).

For the purpose of these antenna evaluation measurements, the antennas will be equipped with so-called evaluation receivers. This receiver system is not the ultimate ALMA receiver, but rather a system of available, well-proven designs of SIS and HFET frontends. This is the fastest and simplest solution to the task of evaluating the antennas. To support the receivers, a system of electronics including LOs, IF processing, accurate detectors, correlator, control communications and real-time computing is needed. To the extent that the schedule permits, these will be prototypes of the devices needed for the array. Also needed are a holography system and a nutation mechanism for the subreflector, with appropriate controls and software.

The evaluation receivers and other electronics must be delivered and proved to be working correctly before the antenna testing can proceed. This sets the initial schedule and limits the extent to which prototype electronics can be used. Thereafter, detailed tests of the antennas and of the electronics will proceed together, with the antenna tests having priority if a conflict should arise. As development and testing proceed, modified hardware and software may be installed to replace initial expedients with prototypes closer to the intended final design, or to correct design errors. The timing of such installations will be a matter of engineering judgment so as not to compromise ongoing tests.

This *ALMA Test Interferometer Project Book* (TIPB) describes the complete system and subsystems as are planned for the single dish and interferometric tests at the VLA test site. Parts of the system – notably the antenna itself, but also many electronics subsystems – will be described in the *ALMA Construction Project Book*, so this *TIPB* concentrates on those parts of the system that will be particular just to the VLA test site installation and tests.

2. Antenna and Prototype Electronics Tests

Two prototype 12-m antennas will be delivered to the VLA site in the fall of 2001. NRAO has contracted with Vertex for the delivery of the one prototype, while ESO has contracted with EIE for the other version. Each of the antennas will be tested to determine its parameters and its adherence to the specifications. In particular, *reflector surface accuracy and antenna pointing behavior will need to be determined under a wide range of operating conditions*. These tests should be done in a time span of about one year in order to meet the schedule of April 2003 for the contract of the production of the 64 antennas.

For the tests of the antennas, they will be equipped with a special holography receiver to measure and set the surface, and with a separate set of astronomy receivers at 8, 3 and 1.3 mm wavelength for establishing the pointing model and to perform further pointing and aperture efficiency measurements. The correlator for the test system will be a clone of the GBT spectrometer, capable of single-baseline cross-correlation for interferometry as well as autocorrelation for single-dish tests. This device is substantially different from the array correlator, a prototype of which will not be available until late in the test program.

The ALMA antennas are specified to perform well at the short submillimeter wavelength of 330 µm. Thus the surface accuracy is specified at 25 µm (goal 20 µm) and the pointing accuracy, between calibrations, should be better than 1”. It is a challenging task to measure the antenna characteristics astronomically to a precision sufficient to confirm the specifications. The use of a terrestrial transmitter as the prime holographic signal source should nevertheless permit sufficiently precise measurements of the antenna surface, albeit at only one elevation angle.

The prototype antennas will also be used for the initial tests of special metrology systems, which have been included by the antenna contractors or are developed by the ALMA consortium. A preliminary program of this work is included later in the PB.

Of equal importance is the measurement of pointing stability under influence of wind and solar radiation. Obtaining a pointing model with arc-second accuracy will not be easy in view of the relative scarcity of sufficiently strong pointing sources at 3 and 1.3 mm wavelength. Separating wind induced pointing variations from atmospheric (refraction) effects may be difficult. The tests of the pointing behavior of the antennas could be a time consuming effort. For a meaningful comparison between the two antennas at this level of accuracy, it might be necessary to perform many of the tests in the domain of environmental influences with both antennas simultaneously.

The stability of the reflector surface under gravity, wind and temperature changes needs to be carefully measured to determine the submillimeter wavelength quality of the antennas. Lacking a metrology system to measure the shape of the reflector at arbitrary elevation angles in "real-time", in single dish mode this can only be done by the measurement of aperture efficiency and beam maps. It might be feasible to obtain useful data from a series of holography surface maps, obtained under varying conditions of wind and thermal regime (both sufficiently stable over the time of the holography measurement). However, as soon as both antennas are operating in a sufficiently reliable and reproducible way, and adequately debugged and reliable electronics to support interferometric operation is available, then interferometric holographic observations on, for example, the strong SiO maser sources at ~86 GHz will become possible. Such astronomical measurements will become an important part of the antenna test procedure – the prime measurement of large scale deformations as a function of antenna elevation. Interferometric tests will contribute further, essential knowledge about the antenna behavior, such as a quantitative check on the specified 15 µm wavefront stability of the antennas when operating together as an interferometer.

The initial antenna measurements **must** be performed in single dish mode. Interferometric operation puts different demands on the electronics – such as phase stability and coherence of the local oscillator systems, and some necessary degree of confidence in the overall operation of both antennas and electronics. Some measurements can **only** be performed in interferometric mode, while some other measurements, perhaps including pointing studies, may be performed equally well in single dish or in interferometric mode. During the antenna test period, engineering judgement will be used to decide at which point to switch from predominantly single dish to interferometric testing.

There is also a need to install and test prototype ALMA instrumentation on the test interferometer before starting the mass production of this equipment. The schedule for the development of the ALMA instrumentation does not allow these tests to be delayed until the antenna test program has been completed. Thus, we need a test schedule whereby both objectives can be realized with as little mutual interference as possible. Once the antenna tests have been finished, the TI will be available fully for the further testing of prototype ALMA instrumentation and software.

3. Future Revisions to this Project Book

Finally, this *TIPB* is to be considered a living document. Inevitably, as our planning and instrumentation development for the TI continue, there will be changes; regrettably but equally inevitably, this first version of the *TIPB* (February 2000) will likely contain errors, omissions and inconsistencies. The editors (DTE & JWMB) ask readers to draw our attention to such errors. The latest and definitive version of this *TIPB* will always be that available on the WWW.

JWMB & DTE, 2000-02-17