Report on the ALMA Photonic Systems PDR

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This is a report on the ALMA Photonic Local Oscillator and Phase Calibration PDR. It is especially significant in that it is the first to involve complete European participation in the new joint project. The PDR followed the guidelines established in the earlier MMA project and took place in Tucson on the 28th and 29th of September 1999.

The Review Panel

The Review Panel consisted of the following:

Darrel Emerson (NRAO, Chair)
Brian Ellison (RAL)
Harold Fetterman (UCLA)
John Payne (NRAO)
John Pearson (JPL)
Richard Sramek (NRAO)
John Webber (NRAO)
Sander Weinreb (JPL)
Wolfgang Wild (SRON)

Introduction

The list of presentations given at the meeting is below. This report will not attempt to summarize these various presentations but will focus on the recommendations of the Review Panel. Prior to this meeting, NRAO had been considering three separate photonic options for the ALMA receiver systems. "*Option I*" is purely conventional, with the transmission of a relatively low frequency reference (e.g. 13 GHz) signal over optical fiber, using off-the-shelf fiber optics modulators and demodulators. In "*Option II*" a LO reference signal up to about 120 GHz is generated at a central site, as a difference frequency between two lasers. The 2 lasers signals are then sent out along a single fiber to each antenna, where a photodetector generates the ~120 GHz microwave signal. This is then used to phase lock a local YIG or Gunn oscillator; higher frequencies, into the sub-mm region, are generated by a succession of multipliers from this signal. "*Option III*" is a further development, where the LO signal is generated at the central site as a difference frequency between 2 lasers, over the entire frequency of operation of ALMA. This signal is sent to each antenna, where a photodetector produces the needed LO frequency at the receiver directly, without further phase locking or multiplication.

Option II had been chosen by NRAO as its favored basline plan, although it is hoped that Option III may eventually be developed to a sufficient degree that it becomes a viable alternative - leading to considerable simplification of the receiver systems.

SUMMARY OF THE AGENDA:

Introduction - Scope and goal of this meeting — Darrel Emerson

Specifications - Summary of scientific requirements and how they translate into engineering specifications — Darrel Emerson & Simon Radford

US Baseline Design:

1. LO Baseline Plan - Description and rationale — Larry D'Addario
2. Test Interferometer LO Plan — Larry D'Addario

Photonic Systems:

1. General introduction to photonic LO issues — John Payne
2. Phase locking, round trip correction, photomixer development — Bill Shillue
3. Photonic phase calibration - Systems aspects and implementation — Darrel Emerson & Andrea Vaccari

Multipliers and LO source generation

(This section is strictly not part of this design review, having been presented at an independent PDR. However, presentations were included in order to put the photonic development in context within the overall system.)

1. LO sources (locked to reference) — Skip Thacker/Eric Bryerton
    a. Details of LO generation and meeting the phase specs
    b. Current status and results.

2. Mmwave Multipliers — John Webber
    a. Current status
    b. Research areas - Frequency plan; amplitude noise

European Activities

(This meeting is the first joint PDR with the Europeans. Although plans within Europe are inevitably not yet so advanced as those from the US, a summary of European capabilities was presented.)

1. European photonics plans and activities — Rolf Guesten
    (presented in Guesten's absence by John Payne)

2. UK activities — Brian Ellison

Schedule and timeline

The schedule and timeline — Larry D'Addario

Discussion on US/European collaboration — All

The Panel's Comments

1– The approach taken for the baseline plan, in the photonic distribution of the reference to each antenna ("Option II") is good and the correct choice. "Option III" is still attractive, provided that it can be shown to be viable in an appropriate timescale. Thought should be given to a possible upgrade path from Option II to Option III.

2– Specifications: Some areas require further work. The tuning granularity of the first local oscillator was a subject of some discussion. The noise floor of the first local oscillator as it affects the dynamic range of single dish observations needs to be added to the list of LO specifications. The oscillator switching times, both for single dish frequency-switched observations with a limited range of frequency switching, and for general tuning within a single receiver band, may need respecifying; the former may need a faster response (1 ms?), while the latter requirement may be relaxed (1 second?) The LO power requirements were not well defined, and have perhaps been unnecessarily overestimated by the mixer designers in order to ensure an adequate margin. Since power is expensive at sub-mm frequencies, this area deserves more careful study.

3– A more detailed analysis of phase noise in all parts of the LO chain should be made, including the performance of the various phase lock loops. There are many sources of noise in solid state lasers, and further investigation is needed. Conclusions should be written up in a readily available form, probably part of the ALMA memo series.

4– Some members of the panel felt that the physical properties of optical fiber, for example dispersion and standing waves, had not been adequately studied. Again, studies should be written up in a readily available form.

5– Increased effort on the photonic calibration system was encouraged; this should be given at least as much attention as the round trip correction schemes (which themselves become part of the calibration system).

6– The panel felt that a major effort should be mounted for the ALMA personnel to fully acquaint themselves with the work being undertaken by various groups in high frequency photonics in the U.S., and in Europe. More manpower may be needed in the photonics group in Tucson; a detailed study of the list of tasks and labor estimates would show precisely how much extra manpower might be required to meet the schedule, but there

seems to be an immediate need for at least one extra engineer and one technician.

7– Collaboration with the Japanese was strongly encouraged. An effort should be made to acquire an NTT diode, even if purchasing a new mount and cutting the diode out of it is required.

8– It was felt that although the approach is basically sound, the schedule is ambitious and aggressive and more detailed and careful planning is required.

Conclusions

The panel was supportive of the decision to adopt Option II as the baseline design for the array. There should be a clear path towards the realization of Option III. There should be an increased effort in both the high frequency photo detector work and the photonic calibration system. More manpower in the Tucson photonics group may be required in order to have a working system by the time the antennas are delivered.

The panel agreed that a top priority should be for ALMA staff to visit other groups in the U.S. and Europe to learn of efforts in the development of high frequency photodetectors.

The path adopted is fundamentally sound, but some more careful definition of specifications, and some further detailed studies in a variety of areas as outlined above, were recommended.