



# Atacama Large Millimeter Array

ALMA Correlator Critical Design Review Oct. 1-2, 2003

## FINAL REPORT

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## Introduction

This report summarizes the discussions, activities, recommendations, and conclusions of the ALMA Correlator Critical Design Review (CDR) held at the NRAO NTC Auditorium in Charlottesville Virginia on October 1<sup>st</sup> and 2<sup>nd</sup> 2003. The review was held to verify that the correlator design satisfies the requirements, is compatible with other items of equipment, facilities, software, and personnel, to assess any items of risk, and to ensure that the production plan for the correlator is satisfactory. The attendees at the review consisted of the formal review committee, presenters from the correlator design team, and other observers and technical experts either directly or indirectly associated with the ALMA project. The members of the review committee are as follows:

- Alain Baudry – Correlator IPT Deputy, Observatoire de Bordeaux
- Jody Bolyard – Internal Member (Safety), NRAO
- Brent Carlson – External Member and Chair, National Research Council Canada
- Hans Hinteregger – External Member, Haystack Observatory, MIT
- Chris Langley – Internal Member (Backend), NRAO
- Bill Porter – Internal Member (Business), NRAO
- Steve Scott – Internal Member (Computing), Caltech
- Christoph Haupt – Systems Engineering IPT Deputy, European Southern Observatory
- John Webber – Correlator IPT Leader, NRAO
- Al Wootten – Science IPT Leader, NRAO

And, as observers, Massimo Tarengi, ALMA Project Director, Marc Rafal, ALMA North American Project Manager, Richard Kurz, ALMA European manager, Larry D'Addario, Systems Engineering, and Fred Lo – Ex Officio, NRAO

## Scope

The ALMA Correlator CDR is a review of all items under the responsibility of the Correlator IPT (Integrated Product Team). This is defined as product number 60.00.00.00 in the *ALMA Product Tree* document ALMA-80.03.00.00-001-L-LIS. The CDR contained presentations on the Digitizer status, the DTS (Data Transmission System), and on the Control and Data Acquisition Software, but these items are not under the scope of the review. Additionally, the CDR reviewed the *feasibility* of the European “tunable filter card” and the NRAO poly-phase filter card options, but they were not under critical review by the committee.

The correlator requirements are defined by ALMA science requirements. More specific detail on correlator requirements can be found in ALMA document, *64 Antenna Correlator Specifications and Requirements*, ALMA-60.00.00.00-001-A-SPE.

Design review procedures are contained in the ALMA document, *ALMA Reviews, Definitions, Guidelines, and Procedure*, ALMA-80.09.00.00-001-A-PLA, Version: A, 2003-08-14. To the best of everyone’s ability, the CDR followed the procedures outlined in this document.

## **Summary Statements from the Committee**

**The baseline correlator design reviewed by this CDR is *SATISFACTORY*, but requires follow-up of some concerns and actions items. Only those parts of the design that have no concerns and action items should proceed with procurement.**

**The committee would like to congratulate the Correlator IPT on excellent effort and results in the design and testing of this system.**

## Recommendations and Action Items

This section contains a list of recommendations and action items distilled from notes taken at the CDR, and follow-up emails provided by committee members. In this section, anything that is not specified as a recommendation is a *required* action item. Anything that is specified as a recommendation is not a required action item, but is rather an action the committee feels should be performed.

1. The committee unanimously recommends that the European “tunable filter card” be adopted by the Correlator IPT into the baseline design, and that further detailed design work on the new card continue. This card will replace the existing filter card and will possibly remove the ability of the correlator to operate in the “time-multiplexed” correlation mode. The tunable filter card will build on the existing infrastructure of the correlator, improve the spectral channel capacity in wideband modes by more than an order of magnitude, allow for independently tunable sub-band widths and placement in the wideband, and potentially have no cost and schedule impact. The fallback position, if the tunable filter card is somehow found to be infeasible, is the existing filter card.

There are several action items associated with the tunable filter card recommendation:

- A proposal has to be prepared detailing the work that needs to be performed for the enhanced filter. Such a proposal shall comprise the following information:
  - i. Schedule and cost information.
  - ii. Functional and performance specifications.
  - iii. Statement of Work.
  - iv. Work Plan.
- G. Comoretto of the European Correlator IPT must further study, quantify, and demonstrate with simulations the ability for the sub-bands to be seamlessly stitched together. This work must be documented in an ALMA memo within the next few weeks. Seamless sub-band stitching is important because with this filter the correlator may no longer perform “time-multiplexed” correlations as with the existing filter card.
- The Correlator IPT has stated that by Q4 2004, 10 working prototypes of this card must be available for testing in the system (Baudry has stated in a follow-up email that a minimum of 3 cards and a maximum of 10 cards is required for this test). These prototypes can use the Altera FPGAs for the filters at ~70 W power dissipation per card, rather than the Altera Hardcopy<sup>1</sup> chips for the filters at ~45 W power dissipation per card. The

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<sup>1</sup> The “Hardcopy” chip is an Altera process where the FPGA is frozen into a cheaper, lower-power, functionally equivalent, non-programmable component. Altera guarantees that this is a no-risk process.

production version of this card will use exactly the same circuit board, just with the Hardcopy chips instead of the FPGAs. R. Escoffier would like to see the prototypes built with slightly larger, pin-compatible, FPGAs in case some unanticipated design/function changes are required.

- The Correlator IPT must make some minor changes to the station motherboard into which the new filter card will plug in. This constitutes a re-spin of the backplane, with no major design work involved.
- The production tunable filter cards, complete with the Altera Hardcopy filter chips, for the first quadrant of the correlator must be delivered by May 2005. At this point, the full set of software required by the new card must be ready for testing. This schedule allows for a reasonable length of time for integration testing before the first quadrant is shipped to Chile.
- An official JAO decision to use the tunable filter card should be undertaken expeditiously so that other ALMA IPTs can make adjustments as necessary to accommodate the new requirements (e.g. sub-band stitching requirements in the Computing IPT).
- The committee recognizes that with the tunable filter card, the need for an optical cross-bar switch in front of the correlator is eliminated.

Furthermore, the committee recommends that the Correlator IPT investigate the feasibility of having the tunable filter card's filter chip include the ability to perform earth-rotation phase corrections and very fine delay tracking (i.e. +/-  $1/64^{\text{th}}$  of a sample). The investigation should include any trade-offs between filter performance and the implementation of these phase shifts. (A follow-up email from B. Carlson indicates that wideband delay tracking to +/-0.5 samples at 4 Gs/s will *probably* have to be on the filter card if the very fine delay tracking is to be performed). ALMA System Engineering will use the results of the investigation to determine if there will be any changes to the system design.

2. In addition to the complete design, including circuit board level schematics, FPGA schematics, and all documentation, a complete set of development software must be kept and frozen with the design to ensure that it is possible to maintain and/or modify the design to fix bugs and/or add enhancements at some future date.
3. 31.25 MHz narrowband operation is confirmed by the committee as a requirement.
4. The correlator racks and installation must meet certain earthquake standards as defined by the System Engineering IPT. These standards will be provided to the Correlator IPT, and the Correlator IPT will look at the precise construction of the racks, floor, and installation, and do calculations and modify the design to ensure that the earthquake standards are met.

5. The committee recommends performing a formal reliability analysis of the correlator to determine the system MTBF (Mean Time Between Failure) so that spares and lifetime buys of components and relevant equipment can be adjusted accordingly. Depending on the results of this analysis, some accelerated life testing may be necessary to empirically determine reliability. Apparently, software is available to assist with the calculation, and a reference to this software will be provided to the Correlator IPT by Jeff Zivick of Systems Engineering.
6. ALMA System Engineering is to provide the Correlator IPT with specifications on required Bit Error Rate (BER) throughout the correlator system (from the DTS to the point of where cross-correlations occur).
7. The committee recommends that a polarity and color code for the 48 VDC supply be standardized throughout the correlator and all ALMA systems. It is noted that the (telecom) industry standard is that the supply is a negative (-) 48 VDC supply.
8. Although not part of this review, the committee recommends that an embedded “station ID” be inserted into the DTS at the antenna to be extracted by the correlator. Since this is not part of the current design, it is recognized that this could be difficult or impossible to implement, but it should be explored if possible.
9. The Correlator IPT has noted in a presentation that there is a non-zero error rate in the internal data transmission system from the Station Interface Card to the Correlator Interface Card. Although the error rate is probably acceptable, the *reason* for these errors is unknown, and the committee recommends that the reason be quantified or the problem fixed before proceeding to production. (A follow-up message from R. Escoffier on October 13, 2003 notes that some progress has been made in solving this problem by making some FPGA design changes, and more importantly removing some clock line termination resistors. However, further investigation and mitigation of this problem will continue.)
10. The committee recommends that the Science IPT clarify the conditions under which the spectral dynamic range of 40 dB is required. Since the ALMA correlator is a 2-bit correlator, the dynamic range can only be achieved if the narrowband power into the receiver is less than a certain small fraction of the total receiver power. The Science IPT must quantify what the maximum total narrowband power is into the receivers, as a fraction of the total receiver noise power.
11. The science specifications indicating what the maximum sensitivity loss of the correlator must be, should be further clarified. Nominally, with the European tunable filter card and a 2-bit correlator, the sensitivity loss in the correlator is  $1 - (0.88 \times 0.985) = 13.3\%$
12. The System Engineering IPT will provide the Correlator IPT with all applicable approved requirements documents that the correlator must meet, and the



Correlator IPT will respond appropriately. The final response could most clearly be in the form of a compliance table.

13. The correlator chip truncates the last few bits of the accumulators. The committee would like the effect of this to be quantified to ensure that it does not have any adverse effect on any requirements (such as spectral dynamic range). The Correlator IPT is to perform this analysis and report it (the best way is probably to write an ALMA memo).
14. The committee recommends that the Correlator IPT complete and approve the documentation as required in the CDR *ALMA Reviews, Definitions, Guidelines, and Procedure* document.

## Individual Committee Member Comments

This section contains a record of individual committee member comments obtained during the committee-only meeting at the end of the CDR, from copies of follow-up emails from committee members, and, where necessary, from notes taken by the chairman. These notes, in addition to the above recommendations and action items, should be carefully considered by the Correlator IPT.

### **Alain Baudry (correlator management):**

1. My understanding is that with the tunable filter card, the need for the optical cross-bar switch is eliminated. The major reason for the cross-bar switch is to chain lags across quadrants, but with the improved spectral channel capacity, chaining lags is no longer needed. The committee should note that this is the case.
2. The only other reason for the cross-bar switch is for redundancy if a correlator quadrant is down. However, should be able to re-route around this problem using another I/F.

### **Jody Bolyard (safety):**

1. The modular nature of the cards and the replacement was discussed. In particular, the card diagnostics are planned to be conducted at the OSF and the work done on the correlator limited to minor diagnostics and card replacement. All repair of damaged cards and components will be done at the OSF.
2. The identification of the cards is critical. Ease of use and identification is important. This can be done through labeling and education.
3. Associated with the card replacement certain affected cards may be removed and replaced while the correlator is powered up. This is possible by the presence of breakers on individual cards. In addition, the correlator must be equipped with the means for ensuring power is removed for more extensive maintenance. This needs to be in the form of lockouts on the breakers or other electrical controls.
4. With respect to training, there is currently no training program in place and is anticipated to be part of the operational documentation. The training must include the proper procedures for identification and removal of cards as well as the proper maintenance and lockout procedures.
5. The Correlator IPT need to further define the fire protection requirements to the Site IPT to ensure the appropriate protection is installed in the facility.
6. The QCC has pre-established limits for overheating and monitors the correlator environmental conditions. The protective devices need to be in place to ensure

- power shutoff in the event of card failure/overheat. This is in the form of a shunt trip.
7. It is my understanding that the correlator itself has no requirements for ambient oxygen requirements and that the requirement in the hazard analysis was due to the need of personnel working on the system. It is the responsibility of the Site IPT to deal with this issue.
  8. The correlator will be moved during the move to the NTC from the Ivy Road site. This move needs to be a trial run of the transport plan for Chile as the correlator IPT responsibility extends through the Chile move.
  9. Earthquake design was discussed at length. The IPT will need to contact an (NRAO?) engineer to design solutions for anchoring and stability protection for the correlator in Chile. This will be done in accordance with the seismic specs for the ALMA project.
  10. The environmental conditions expected in Chile will not adversely impact the life of the components as the room will be humidified and conditioned air provided. In addition, the room is specified to provide a 100000 level clean room to prevent dust accumulation on the components.
  11. In accordance with the hazard analysis conducted by the IPT the following items were included:
    - a. Crushing hazard - This is a class 2D - O assessment. This category was assigned for earthquake design and is being addressed by the seismic design issue.
    - b. Entanglement hazard - Class 3D - O assessment. This is based on the premise that employees will be reaching into the correlator wiring. This is addressed administratively and with the training program to be developed. The presence of lockout as indicated in item 3 above.
    - c. Low voltage /high current hazard - Class 3B - O assessment. This item is also resolved by the use of lockouts to provide safe access and maintenance.
    - d. Electrostatic Discharge / lightning hazard. - Class 3C – F assessment. The electrostatic discharge is managed by the humidification system and the lightning hazard is the responsibility of the site IPT.
    - e. Loading/Unloading hazard - Class 3C - O assessment during delivery. This is addressed fully in the transport plan.
    - f. Lifting /Carrying heavy objects - Class 3C- O assessment for lifting power supplies. This is best addressed by administrative controls and during the training session. The frequency of this is minimal.

- g. Earthquake - Class 2E - F assessment. This is addressed above as well.
- h. Electrical - Class 1D - F assessment. The electrical hazards need to be addressed by the IPT. The issue is protection of personnel working on the correlator. Proper protection needs provided to ensure no exposed electrical wiring is accessible. This may include interlocks, protective barriers, as well as education.
- i. Fire Suppression Systems - Class 1D - F assessment. Fire suppression needs addressed as indicated in the item 5 above.
- j. Ventilation - Class 3C - F assessment. This is the responsibility of the Site IPT.

### **Brent Carlson (external reviewer and chair)**

1. I strongly recommend that the production units that are to be installed in Chile undergo burn-in testing before shipment. This is different than accelerated life testing used to determine reliability or to find design flaws. It is testing that is used to try to weed-out most of the infant mortality that could be experienced in the system. Although I don't have any specific requirements for this testing, past experience in industry has demonstrated that a 40 °C burn-in for 100 hours should be sufficient. Perhaps some more investigation by the Correlator IPT could be done to better quantify the burn-in parameters.
2. I highly recommend that a 48 VDC polarity standard, and power cable color code standard be developed for not only the correlator, but for all of ALMA systems.
3. I strongly and enthusiastically endorse the European tunable filter option, as well as performing the earth-rotation phase tracking and very fine delay tracking in the tunable filter card. This will simplify many ALMA systems, and remove complicated synchronization issues with the antennas.
4. I had some concerns about hot-swapping modules in the correlator. There seem to be no specific requirements for the correlator, and the existing plans seem to be sufficient, given that normally there won't be any personnel on the high site, and that the MTTR (Mean Time To Repair) of a "couple of hours", once someone is on site, seems adequate.
5. I have concerns about production of a large number of circuit boards with gull-wing quad flat-pack surface mount devices on them. Past experience has shown that there can be production yield problems with this technology. The Correlator IPT's plan to only accept boards from the assembler once they have been tested, and to not build all quadrants of the correlator at once, seems to adequately address this concern (although, I would add that the burn-in should be done before acceptance as well for additional margin in detecting solder faults).

6. The correlator chip truncates the last few bits of the lag accumulators. Is it known what effect this has on spectral dynamic range? It has been “done in the past”, but perhaps the spectral dynamic range requirements of this correlator are greater than in the past.

### **Hans Hinteregger (external reviewer)**

1. Overall baseline correlator CDR presentations – excellent.
2. Tunable filter enhancement conceptual/preliminary presentations excellent.
3. “Nitpicks”:
  - a. Signal interfaces - observed flakiness needs to be understood to be reliably fixed.
  - b. Reliability - elevated temperature failure rate tests needed, tall-pole identification needed if unexpectedly high/sensitive.
  - c. Tunable filter - further analysis, tests for unanticipated artifacts needed.
4. System issues - digitizer, DTS design, archive link - outside scope of this CDR, but problematic choices are apparent to me.
5. A very interesting and informative meeting from my perspective.

### **Chris Langley (back end)**

1. Changing to a negative 48 VDC standard. DTS boards use isolated power supplies, so there should be no problem running them off of negative 48 instead of positive 48 VDC - unless the relative polarity of the Correlator Station Bin backplane power feed has been reversed from the standard defined in the BE to Correlator ICD. Regardless, the next revision of the DTS digital de-formatter will provide for negative 48 VDC input power. Should the BE to Correlator ICD be revised to call out negative 48 VDC?
2. Station bin receiver slot addresses. Each correlator station bin DTS receiver assembly slot shall have a hard encoded address (7 or 8 bits, TBD). These signals will be sent to each receiver assembly through the hardmetric backplane connectors, where it will be picked up by monitor and control. This needs to be defined in the BE to Correlator ICD.
3. EDFA Safe Signal. Each DTS receiver assembly sends a "Laser Safe" signal to the station bin backplane. From the backplane, this signal is to be routed to a corresponding EDFA so that that EDFA may be shut down in the event of optical signal loss. The wiring scheme between the station bin backplane and the EDFA still needs to be defined, presumably by Backend personnel in the BE to Correlator ICD.

4. Decoding of data by digital de-formatter. The digital deformatter has no provision to decode data (ie - Grey Code from Digitizers). This should be made clear in the BE to Correlator ICD.

### **Bill Porter (business)**

1. I would like to thank John Webber for putting a business manager on the review committee. The ALMA project will require a close co-operative effort of everyone, and including a business manager on the committee helps to foster co-operation.
2. Christoph Haupt's suggestion for a requirements compliance table is a good idea, based on previous experience with antenna manufacturers. Production of this table requires that the contractor read the requirements specification very carefully and proves that they know they can do the job.

### **Steve Scott (computing)**

1. The approach being taken of procuring all boards and components, including spares, at the same time is strongly endorsed. The avoidance of the parts obsolescence issue is a very positive attribute. Along these lines, it is recommended that some form of accelerated lifetime testing be done and the results used to verify the quantity of spares.
2. The prototype work that was demonstrated in the lab was impressive and gives evidence that the correlator is on schedule.
3. Burn in for the production boards at elevated temperature is recommended
4. A design for correlator rack mounting with respect to earthquake hazards is needed, taking into account personnel safety and protection of the correlator. A grounding design needs to be developed.
5. The tunable digital filter concept presented, with more channels and the minimization of aliasing, is regarded as a very positive increment in the capabilities of the correlator and should be vigorously pursued. This is a new development and the concept, along with all of its ramifications, needs to be fully embraced by everyone in the Correlator IPT. The schedule is very tight to have the tunable filter be part of the first correlator quadrant shipped to Chile.
6. Stitching the bands together after removal of the aliased edges, followed by smoothing and decimation is essential to reduce the data rate to a level acceptable by the archive. These computational steps will have to be done in the CDP computers, which requires that the algorithmic steps be carefully defined so that processing loads can be estimated. Any additional calibration measurements required must be identified. It is clear that the tunable filter will result in a

significant increase in the complexity of the realtime computing and should be analyzed by the Computing IPT.

7. With the addition of stitching to support the tunable filter, it is reasonable to ask if stitching should also be supported between the IF bands. While this is scientifically attractive, it may prove to be technically infeasible because of the communication between CDP nodes that might be required. This is not specifically a correlator issue, but system-wide ramifications should be explored when a change is proposed.
8. There seems to be an organizational issue with regards to the responsibility for the algorithms to turn the counts produced by the correlator hardware into accurate scientifically useful quantities. The current example is the digitization correction from the samplers and fir filters but the tunable filter has the same issues plus the new area of sub-band stitching which has not been previously implemented anywhere. The list of potential victims includes Correlator, Computing, Science or System; but the choice should probably be made on who has the unique resources to tackle the problem.

## **Christoph Haupt**

1. Documentation:
  - a. Some documentation is missing or not complete.
  - b. Most of documents are draft only and not approved.
  - c. There was not enough time to review the documents as some docs were delivered only a few days before the meeting (*chairman's note: the late availability of the documents was due to the recent hurricane on the U.S. east coast*).
  - d. The reviewers should be given more time (2 weeks) to read and review the documents. Documents needs to be approved according to the approval process.
2. It was not possible to assess the provided design based on the design documentation regarding compliance to the Engineering Specification. That needs to be done. SE will provide a list and copy of these documents to the CORL team. (AI for SE).
3. Scope of the review meeting was the Correlator according the product tree. The tunable filter and SW was not under review.
4. A change request for the tunable filter has to be prepared to change the baseline correlator (date should be indicated), including a trade off, justification, specification and a detailed financial and schedule plan.

5. The CDR compliance matrix needs to be extended.
6. Action items:
  - a. Provide to SE (Christoph Haupt) documentation on CORL power supply (AI for CORL).
  - b. Provide parts list to SE to conduct a reliability analysis (AI for CORL).
  - c. Ensure the compliance of the CORL racks with environmental spec, e.g. earthquake (AI for CORL).
  - d. Prepare grounding diagrams (AI for CORL).
  - e. Provide comments to provided CDR documentation (AI for Review Panel).

Additional notes from Christoph via email:

### **1. Subsystem Specification**

Is this version the latest one (dated 2002-07-01)?

It is more a design description document than a technical specification.

It is not in the ALMA format but copied from the Project Book (Starts from chapter 10). This document has not been approved and released on its own but as a subsection of the Project Book.

References to ALMA documents (e.g. standards, design requirements, environmental specification...) are missing.

### **2. Prototype Testing**

This is a mix of test plan, test results...

A conclusion for each test and an overall conclusion are missing: how do the results guarantee that the Correlator has attained its final design?

What is good what needs improvement? What are the risks identified for the following phase? Which decisions have been taken following those tests?

How does this assess that the subsystem design meets the specification?

### **3. Compliance Matrix**

The list of requirements should be more detailed and refer to the relevant specification chapter.

It should be indicated how we have come to the conclusion it was compliant (Design/Analysis/Inspection/Test) and referred to a reference document (e.g. test report, design document...).

### **4. ICDs**

Front pages should read ICD “between” two subsystems and not “from” one “to” the other.



The ICDs must be authored by one representative from each IPT (i.e. both IPTs agree on the content of the ICDs).

ICDs give requirements: “shall” instead of “will”.

*ICD between Site (AOS Technical Building) and Baseline Correlator:*

- It is not only interface with AOS TB but also OSF TB which is described here: change the title and number (ICD between Site and Baseline Correlator, ALMA-20.00.00.00-60.00.00.00-A-ICD)

*ICD between Correlator and Computing:*

- Many of the reference documents (on software/control function interface which are essential documents for this ICD) are TBD.

*ICD between BEND and Correlator:*

- Give titles of Reference documents.

##### **5. Reliability, Maintenance and testing of the ALMA Correlator**

Test plans, procedures and equipment which are mentioned in 4.1 are maintenance test plans.

Acceptance and/or qualification test plans and procedures are also required for the CDR.

At least, the different plans and procedures which are foreseen for the Correlator (Acceptance, maintenance...) should be listed.

Life cycle costs: estimation of the yearly (for instance) costs should be mentioned.

There is no figure available.

##### **6. Correlator Hazard Check List**

What is the meaning of letters and figures for Severity, Probability and Scope?

Many of the listed potential hazards are not rated.

The ones not applicable should be noted NA or removed from the list.

How far is it compliant with Project Safety requirements?

### **John Webber (correlator management)**

1. Reminder to System Engineering that the Correlator IPT needs to know the max BER that is required within the correlator.
2. In order to produce a requirements compliance table, System Engineering must supply all relevant requirements documents to the Correlator IPT.

### **Al Wooten (science)**

1. I feel that the correlator meets the science requirements. I can't think of any other ALMA system in which I have more confidence.
2. The tunable filter goes some way toward fulfilling some 2GC requirements. Approve the baseline filter card but recommend pursuit of the tunable filter.

3. I'll need to collect Science IPT, ASAC comments so a list of modes with tunable filter; examples, including four bit examples.
4. How fine does the (spectral) resolution get?
5. The science possibilities enabled by the tunable filter are varied and exciting; the Science IPT can provide specific examples.
6. Given estimates of expected phase errors at sub-band bounds, Science IPT will attempt to calculate the effect of these on image fidelity.
7. What modes are implemented on the prototype correlator? Answer--this has been defined, a few modes will be supported as defined by D'Addario.
8. What are plans to calculate the digitization corrections? Fred Schwab has said he could do this but action has not been forthcoming.
9. Dynamic range action item. Science IPT should supply the strength and width of the strongest expected line so that the Correlator IPT could ensure that the dynamic range spec is met.

## Question and Answer Sheets

During the meeting, the committee members and other attendees were asked to write down any questions to presenters and to record the answers on question and answer sheets. The purpose of this procedure was to try to ensure that there is an accurate record of the questions and answers in the meeting, since the committee was not provided with a dedicated person to record the minutes of the meeting (see, however, Meeting Notes from B. Carlson and A. Wootten in the Appendix). This procedure was only marginally successful, nevertheless the results are recorded in this section.

### Session: Single and Polyphase Filter Options (Presenter: R. Escoffier)

Questioner: Christoph Haupt

*Could you please summarize which changes are required on the correlator cards, software, other sub-systems, if the tunable filter option will be used?*

Answer:

1. *New filter card.*
2. *New voltage out of the 6 U power card.*
3. *Small changes to station motherboard.*
4. *Change to station card FPGA designs.*
5. *Software (major changes).*

### Session: Power, Site Interface, Safety (Presenter: J. Greenberg)

Questioner: Christoph Haupt

*Are the racks used for the correlator, meeting earthquake requirements?*

Answer:

*No, not taken into account by structural (design?), or procuring the racks according to a defined earthquake standard.*

Questioner: Christoph Haupt

*What is the status of the correlator power supplies (48 V)?*

Answer:

*All correlator power supply units are purchased. (Manual needs to be provide to SE [Sramek and Haupt])*

Questioner: Christoph Haupt

*Do you have a grounding diagram for the correlator racks?*

Answer:

*No, this does not exist.*

**Session: Long Term Accumulator and Final Adder (Presenter: C. Broadwell)**

Questioner: Christoph Haupt

*In which document is the long term accumulator specified?*

Answer:

*There is no specific specification document. A manual exists. However, the LTA card meets the high level specs in the ALMA-60.00.00.00-001-7-SPE doc.*

**Session: Architectural Overview (Presenter: R. Escoffier)**

Questioner: Christoph Haupt

*Is each card self-identifiable?*

Answer:

*Yes, a small chip will provide a card serial number.*

Questioner: Andre Gunst

*Do you have to provide the analog tied-array outputs?*

Answer:

*Yes, but the “add on” card for this is not yet designed.*

Questioner: Brent Carlson

*Why use external LVDS receivers on the cards, instead of in the FPGAs?*

Answer:

*To save pins on the FPGAs, since we are pin limited because we are using QFP devices.*

**Session: Fiber Optic Tx/Rx Status (Presenter: Chris Langley)**

Questioner: Andre Gunst

*How do you know which fiber is connected to which antenna?*

Answer: (Chris Langley + Larry D’Addario)

*You have to do this by hand on a cable panel. There is no provision designed to check for this automatically.*

**Session: Schedule and Budget (Presenter: John Webber)**

Questioner: Richard Simon

*Comments about budget: The original total budget of \$13.5 million (excluding overhead and contingency) did not include significant spares. As of today, about \$1.0 million has been expended, leaving ~\$12.5 million. John Webber's approximate cost to complete of \$11.7 million includes spares at the 5-10% level. Thus, the budget situation appears very positive; these numbers are subject to change and are not official, pending a detailed budget review and formal calculations.*

Answer:

*Yes, the calculation is open and needs to be refined. Probably the least certain number is the cost of the European filter card.*

**Session: Signal Interfaces (Presenter: R. Escoffier)**

Questioner: Brent Carlson

*Is there a possibility of undetected bit slips in the station to correlator interface cards?*

Answer: *No*

**Session: Correlator Chip and Correlator Card (Presenter: R. Escoffier, J. Greenberg)**

Questioner: Brent Carlson

*What about jitter accumulation in the 3 stages of Xilinx chips? Isn't this too much? My concern is with a large number of boards being produced...maybe ok for prototypes, but problems with many boards.*

Answer:

*Seems to be ok. Talked to the Xilinx FAE and he said it is ok. Also, the correlator chip has no PLL/DLL, and so it has no problem with jitter.*

## Appendices

### Meeting Notes

Although no formal meeting minutes were taken, Brent Carlson and Al Wootten were able to take extensive notes during the meeting. For completeness, these notes are included in their “ad-hoc entirety” in this section, but should not be considered an accurate reflection of the meeting or approved content by the committee.

### Brent Carlson’s Meeting Notes

#### Al Wootten: Science Requirements

- retune ALMA to new frequency every 100 msec? Larry D. says no.
- 1 Hz resolution needed? No radar @ ALMA frequencies. Could be at 30 GHz, though.
- talked a lot about 2GC enhancements...38% of proposals require < 1 km/sec resolution.

#### Ray Escoffier: Architectural Overview

- Is final narrowest BW 31 or 62 MHz?...need consistent story.
- Enhancement—mainly requires re-design of the FIR filter card.
- All cards: design complete, prototypes tested, production prototypes tested.
- “Chimney” cooling...has not been tested with full rack thermal analysis done.
- 6A into cards @ 48 VDC—derated pins by 50%? Yes.
- ~2W per correlator chip...runs cool with ambient forced air cooling.
- 9Ux400 mm card – correlator card.
- Room layout: no standard ALMA requirements—set according to engineer’s estimate (1.25 m clearance ok?)
- No optical X-bar—can’t tradeoff lags for basebands—has been put aside. Enhancement will generate enough resolution anyway.
- Cards are self-identifiable—each card has a microprocessor readable S/N.
- Phased-array is a science requirement...but no \$ for VLBI recorder etc. Current phased BW is 62.5 MHz x 8.

#### Alain Baudry: Digitizer status

- not formally reviewed by this CDR.
- everything seems well in hand.
- Grey-code output...code handled by FIR card.
- Would like to see frequency response (ampl+phase) of the digitizer from 2-4 GHz. Frequency response will be measured with specific Digitizer Test Equipment.

Chris Langley: Fiber Optic Tx/Rx Status

- not formally reviewed by this CDR.
- Sampler module: see 130 dB attenuation from shielded enclosure...should keep it from causing interference at the antenna.

Ray Escoffier: Filter Functional Description

- FIR FPGAs, 4W P.D. – may have trouble cooling?
- Several seconds to download new FIR coefficients—due to current s/w, not h/w limitations...can meet 1.5 second requirement with s/w changes.

Ray Escoffier: Signal Interfaces

- 250 Mbps over the station-baseline cables.
- PN only error testing between station and baseline interface card...no on-line connectivity testing capability.
- station—correlator...signal interface error rate problems for entire system. Worst case, bit slips should not be a problem.
- still working on this interface...still some problems need to be worked out. THIS COULD BE A CONCERN.
- system engineering needs to give a BER spec for the correlator.

Ray Escoffier: Station Card

- No concerns...wondering how the delay works?

Joe Greenberg: Correlator Chip and Correlator Card

- 8 different correlator chip modes.
- 3 stages of DLLs on the correlator card using Xilinx. Jitter problems? Does it meet the jitter spec? Correlator chip has not PLL/DLL...should be ok.
- Using SynQor power supplies...no detectable output ripple.
- All signals on backplanes etc. are point-to-point.
- 32 Mbytes/sec output rate with 16 msec dump rate.
- Oversampling—inserts an extra FF between every FF in the delay line in the correlator chip.
- Correlator chip yield: 90%...some bad chips passed mfg's test vectors (2 out of 300)
- Can't and didn't spec the correlator chip MTBF. Would accelerated life testing be useful?

Open discussion

- station-to-baseline sync...calibrate and then let it free run.
- Hans: put sync char on each packet to check line in real time. Ray: no plans to do that.
- Hans: is there a time tick at the antennas? Larry D: 21 Hz reference...astro calibration to nail down final timing...any timing glitches etc. are automatically corrected for...so between calibrations there should be no unaccounted for jumps.

Chuck Broadwell: LTA and Final Adder

- Is 31.25 MHz BW in or out? Everyone: Its in!
- Formal spec for LTA requirements? ... only a manual...but LTA meets all science requirements.

Ray Escoffier: Control Cards

- One control card per bin/crate, except for quadrant control.
- CPLDs will be ISP with JTAG.

Jim Pisano: Control and Data Acquisition Software

- not under review in this CDR.
- Larry D: the CCC should be included in this review.
- Brian Glendenning has said that this s/w is not part of this review.
- CCC—talks to correlator control cards.
- CDP—talks to the LTA.
- WVR data—applied post-FFT.

Joe Greenberg: Power, Site Interface, Safety

- 48VDC power supply mfg: Magnatec.
- no backup for correlator power supply directly...done as part of ALMA site power supply.
- remote control operation not yet defined.
- specified for 13,000 ft, 60°C.
- Should provide system engineering with P.S. specs so it is compatible with ALMA electrical design spec.
- Is grounding the 48 VDC at the rack P.S. a problem? Larry D: shouldn't be grounded at the rack P.S., because defeats isolated P.S. Brent C: can result in undefined DC currents flowing back to the 48 VDC supply.
- Thermal modeling? ...experience...analysis by architectural firm...total airflow, cooling capacity of the room.
- Are racks designed according to earthquake standards? No, not designed to any standard. Is this acceptable? Action: provide committee with rack earthquake standards—i.e. what standards they meet.
- Fire suppression: Halon systems with human safety requirements (i.e. meets human safety reqs)
- Reloading FPGA personalites to mitigate cosmic neutron effects. Is daily enough? Might want to do more often.
- Grounding...is there a spec? What is the plan?
- Safety is to be reviewed by the safety group.

John Webber: Environment and RFI

- Architectural shielding built into the building. No separate screened room for the correlator.



*-RFI in ALMA bands should be ok, based on measurements and some analysis. Not tested with DTS (fiber Rx board) yet.*

#### John Webber: Schedule and Budget

*-Outsourcing the complete assembly...just buying ALMA1 chips.  
-Will not produce the existing FIR filter card to get to Chile...IPT recommends the enhanced filter card.  
-Total cost to complete: \$11.7 M—savings of about 10% over original budget (\$12.4M)  
-~10% spares.*

#### Ray Escoffier: Production Plan

*-Boards are not accepted until NRAO tests them...if bad, ship back to assembler.  
-No plans for on-site assembly testing.*

#### Ray Escoffier: Installation, Operation, Reliability

*-Have extensive PN sequence testing capability throughout the correlator.  
-There is a way to calculate the failure rate from the bottom up...s/w exists to do this. Committee could recommend doing this analysis so spares, lifetime buys can be adjusted accordingly.*

#### Discussion

*-Hans: more effort needed to determine reliability/MTBF...formal calculation? Empirical approach? Accelerated life testing?  
-J. Webber: could do it...not many different types of chips...2 different RAMs FPGAs and correlator chips.  
-Reliability is a big issue affecting spares, staffing etc.  
-J. Webber: we'll do the calculation...see what result is, then do accelerated life testing if necessary.  
-Earthquake: J. Webber: currently looking at the precise construction of the floor and rack. Propose that NRAO engineer do calculations based on design...see if there is a problem. And, look into what is available commercially. May not be able to buy 30" rack size with zone 4 earthquake.  
-Need spec from system engineering on max BER on samples (i.e. wire-by-wire), from the DTS to the point of cross-correlations.  
-Hans: any kind of error rate could indicate that it is on the hairy-edge...the WHY should be nailed down if possible.  
-Ray: possible that some X-talk on station and correlator interface cards...will re-spin the cct brd to hopefully fix.  
-Christoph: electrical specs...should see if there is some conflict...cable color coding etc. Should make 48V wire colors standard throughout ALMA.  
-How does the fiber get labeled from the antenna? This is a matter for the DTS CDR.  
-Hans: it is useful if the fiber contains ID information. But too late to put into the design. Should have an action item to look into the possibility of an embedded ID.*

Ray Escoffier: Single and Polyphase Filter Options

*-poly-phase FIR-FFT filterbank. 4096 taps, cosine transform. Have problems at the sub-band boundaries.*

Gianni Comorretto and Alain Baudry: Tunable Filter Option.

*See A. Wooten's Meeting Notes*

Discussion of filter options

*-3 options: existing filter; NRAO polyphase filter; European 2GC tunable filter.*

*-Brent: I think that the tunable filter chip should include earth-rotation phase correction, and very fine delay tracking capability...simplifies all other associated ALMA systems.*

*-Tunable filter: prototype board with FPGAs—May 04. Ray wants 10 cards with FPGAs. Production boards delivered May 05...s/w ready for testing. This provides a reasonable length of time for integration testing before going to Chile.*

*-Jim P.: has an affect on the data output rate from the LTA to the DPS...problem? Ray: data rate need not change that much...since we have to handle that rate for narrowband spectral-line mode anyway.*

*-In wideband mode, must requantize to 2 bits...in narrower modes, can do 4-bit correlation.*

*-Concern about data rate into the archive.*

Brent Carlson: CDR Requirements Review and Discussion

*-Ray: 1<sup>st</sup> prototype of the tunable filter card should be built with larger capacity FPGAs. The fallback position to this new card is the existing design. Drop dead date: new/old filter card decision for 1<sup>st</sup> quadrant, Q4, 2004. By then, want in place a demo of the prototype filter card.*

*-Sramek: will s/w be compatible with both? Ray: s/w will support min number of modes with the old filter.*

*-Tarengi: new FIR card is proposal of the correlator IPT. Committee make a recommendation to proceed with design work. Correlator IPT makes a proposal to the JAO.*

*-Larry D: Should the baseline design include the enhanced FIR?, and, shouldn't the rest of the IPTs proceed on that?*

*-Tarengi: as soon as the committee's report is received, and the new FIR is recommended, we will open a change request process...when change request is done/decision is made, then it becomes the baseline design. Will try to push the decision through ALMA as fast as possible.*

*-Steve Scott: stitching issue—critical—haven't heard from computing/correlator that this can be done. Ok...committee will recommend that an ALMA memo be produced to look into the sub-band stitching issue...few weeks. Also, list in the CDR report, the benefits of the new filter design.*

*Review of science requirements:*

*-Brent C: need worst-case spectral line power to clarify whether the 40 dB spectral*

*dynamic range can be met with a 2-bit correlator.*

*-Brent C: can the correlator support sub-bands of different sub-band width with the filter card? Ray: Think this is not a problem.*

*-Science spec: correlator losses must be corrected to  $1-(0.88 \times 0.985)$ .*

*-Christoph: more requirements: electrical etc. etc. Does it meet these? Webber: Many ICDs etc. in the review data package. Christoph: need a compliance table...Tarenghi: will build correlator in compliance with all required specs. Christoph: need the correlator IPT to read the requirements docs and say whether they are compliant.*

*Action: system engineering will provide the correlator IPT with all required, approved documents, and correlator IPT will respond.*

*-Why does correlator room need  $0_2$ ? For people...it is a site issue, not a correlator concern.*

*-Steve Scott: can different I/F bands be stitched? Yes, 2 GHz bands can be to a certain extent, but there are analog differences etc. that make this problematic.*

#### Brent Carlson: Committee only discussion

See committee members comments

#### Brent Carlson: Verbal Report to Design Team

1. *Baseline correlator meets all science requirements, congratulate the correlator design team on an excellent effort and results.*
2. *There are a number of issues/action items that will be in the CDR final report...must be followed up by the design team in as timely a manner as possible.*
3. *The committee strongly endorses/recommends the European tunable filter option, and that it get adopted as the baseline plan as expeditiously as possible. Requires some further study/analysis and there will be a specific set of recommendations in the report indicating how this should be carried out.*

*Final Statement: The CDR is satisfactory, requires follow-up of some concerns/action items, and only those parts that have no concerns/action items should proceed with procurement.*

#### **Al Wooten's Meeting Notes**

*Escoffier: Cost follows decline over years since VLA correlator. RS: Is the narrowest bandwidth 32.25 MHz or 62.5 MHz? Answer 62.5 MHz. CH: Will correlator survive earthquakes. 0.28g is the standard. JW: We are meeting that. Loss is 12% with 2 bit correlation. In the room layout, is it too tight? RE: Better than at the VLA; we think it is OK. Power and area of room give  $10^{19}$  Janskys.*

*Room is 11m x 10m. Optical crossbar not planned for money and also since we don't need the highest resolution in this manner when we can get it with the enhanced filter.*

*Each chip has a microprocessor readable serial number. There will be a phased array output. Initial phasing done on the fpgas on the bottom of the correlator card. May not be able to sum up to 2 GHz. As designed, phase to 62.5 MHz per baseband (out of every 2 GHz).*

Baudry: Digitizer (not officially part of correlator). *Sampling and demux clocks have variable phase which differs from antenna to antenna. Samples must be recaptured with fixed 250 MHz clock before FO transport--done well. Changes in bulk delay and fine delay should apply to the same sample--sync within 10 microsec. Decoders in FO card recover original sample bits: sampler bit encoding is Gray-type whereas filter cards expect twos-complement. Sampler design--3bit 8 level 4Gs/s in single asic/flash adc architecture. .25 micron SiGe technology. CMOS transistors and SiGe bipolar transistors (75 GHz transition frequency max sampling design >6 GHz in Jan 03 3bit design (ANTARES). BE CDR completed July 04. Q: Show frequency response at review of this in two weeks time. BC: Fine work done on this critical part of ALMA and eVLA correlator.*

Langley: (Data transmitter and receiver status, also not under review). *Achieved transmission and reception of valid digital data over optical link, using eVLA laser and ALMA optical receiver over 22 km of fiber. Also three optical channels transmitted on a single fiber (joint eVLA/ALMA test).*

Escoffier: Baseline digital filter. *four bit input. 4ghz input. resample to 2 bits. Probably adopt tunable filter card with enhancement to be discussed tomorrow. Can download new tapweights without downloading new personality. These get switched in for each mode of correlator; are ready for each new setup to be loaded in. Takes several seconds to download right now. Native time is 100 msec range but with software (not optimized yet) it is currently slower. From control card flash and control card microprocessor. Not really software but more firmware. This needs to occur within 1.5 secs.*

Escoffier: Signal interfaces. *Cabling mostly between station racks and correlator racks. Cabling needs on correlators. VLA needed 1728. ALMA has 64 ants x 32 demux x 8 BB x 2bits/sample x fanout = 32768 x fanout Difficult to get error-free interface, and low heat. Need fanout as small as possible to achieve this, which drives the correlator architecture. Some discussion on error rates, which are few in  $10^9$ . Optical fiber error rates are 1 in  $10^6$  so this is OK. Bit slips, where the bit gets into the wrong time bin are worse but not expected. Bit swaps would also be a concern. All seems OK but there is room for improvement. Spec should probably be that this error rate not exceed that in the optical fiber. SE should put a spec on this.*

Escoffier: Station card. *Packetizes samples to do time multiplexing. output of two filter cards into station card. Delay tracking not to be covered here.*

Greenberg: Correlator chip and card. *Chip: .25 micron cmos technology 4096 lags, 4x4 antenna array. 2 bit 4 level multiplications. Support oversampling. 32768 chips. 128 bit serial program words so there could be  $2^{128}$  modes. 1.6 w power diss per chip. 16 x 256 lag vlocks in a single chip, 4x4 antenna matrix, 4096 lags out. Card: 64 chips, so 32 x 32 antenna correlations. phased array computation done on this card for all 64 antennas, so there is some redundancy. Currently phased array only does 62.5 MHz but additional summing possible to increase the bandwidth. How much increase is possible is currently being investigated. Antennas going into the sum is programmable--could be one antenna. BC: Xilinx chips have jitter. This may be OK for small quantities but worry in production. There is no time regeneration on board.*

### Lunch.

Broadwell--the LTA, final adder card *(not in two antenna design), data port interface card. Q: is there a 31.25 MHz mode? not much impact on adder. six non-oversampled bandwidths. DS: Can LO steer to a smaller bandwidth? Cost is negligible, it should be included. oversampling mode 1, .5, .25, .125, .0625 GHz. Subarray--independent sets of correlator configuration parameters what may be simultaneously active and applied to antenna sets in a single correlator quadrant. Each correlator quadrant supports a minimum of six correlator subarrays (1-64 antennas per subarray). Provision for a total of 16 sets of configuration parameters (potential for 16 distinct subarrays). Much discussion of subarrays. One could do xx and one could do xx yy xy and yx.*

*Correlator accumulation modes CAM 16 msec lta accumulates 16 msec results cross and auto products available 1 msec no lta 16 buffers of 1 msec results available every 16 msec only auto results available. binning by subarray. all baselines switch at same time. 2 output bins for every baseline (this is for nutators and is a fossil of the time when each antenna was postulated to need one). Switching cycle defined on 16msec boundaries baseline based binning. sideband separation independent for every baseline up to 4 bins for each baseline switching cycle defined on 16msec boundaries by Walsh functions. dump intervals. subarray 16msec, max of 65 sec for 1 bin baseline based min single Walsh--complete complete cycle in 16 msec. 180 deg switching.  $64 * 16 \text{ msec} = 1/024 \text{ sec}$  timing to reconfigure--probably takes 500 msec or so, better than 1.5s fast switching time. Data rates 1 GByte/s 256 MB/s per quadrant 64 MB/s per correlator. reduce data rates by various techniques listed on slide. 62.5 MHz 8192 lags.*

Escoffier: *Control card loads fpga personalities.*

Pisano: Control and data acquisition software. *Not under review LD: Correlator control computer software should be part of this review as the correlator doesn't function without it. Other parts (correlator data processor CDP) are really parts of computing. They do the FFTs. CDP uses WVR data to remove atmosphere from data on .5s timescales. I think this is somewhat odd. Release 1 was 1 October.*

Greenberg: Power distribution *What is the Earthquake standard to which this is spec'd? Does the meet ALMA electrical standards. Grounding document needed.*

Webber: RFI.

Schedule and budget. *Savings with tunable filter is ~\$800K!! New facility can accommodate two quadrants at once. LD: Did the new filter not make any delay? JW: No, since the AOS building was delayed; and we made use of this delay to upgrade to the tunable filter. RS: How many spares? JW: 10% at board level (need 512 ordered 525), more than 20% at chip level.*

*Escoffier: production Plan Failure rates estimated as one card failure every two weeks. Correlator failure points--AC power and 125MHz Quadrant failure points--quadrant control card, a few additional items but not many.*

### Discussion

*Hans: Formal calculation of MTBF should be attempted. The prototype may be some guide also. So do the estimates and if they look high, then do some prototype tests, or tests on the first quadrant. Earthquake. CH: CJ has specified racks good in Earthquake zone 5, OK with ESO mech engineer. But what goes into the racks is also important. One approach--get building specs, then give a mech engineer the data and get him to opine. We will do both--investigate good racks, then get the mech engineer to do the calcs based on the AOS specs. A rack is about 350 kg. Synchronization from station to baseline--interface bin errors. Need a spec on this. SE works with Science to come up with this. Rack to rack cables are only measurable error source expected. Should apply to each bit and not a gross average; state it on wire to wire basis 10-7 or 10-8? Isolate clock line on station and interface cards to cut down on possible crosstalk. Discussion of fibre labelling. There is no digital identification in the system right now. It would be useful for the antenna to do this. This may be done with one bit, serially providing a unique id.*

Friday 3 October

### Filters

*Cost \$1.3M present card, poly-phase, or EU FPGA card. EU FPGA card \$1.8M.*

*Polyphase filter. Are known spectral problems show stoppers? half band frequent switching? spectral point averaging? mathematical correction? Important for what percentage of observations? Oops wrong talk! Now begin correct talk. Polyphase filter converts the baseline correlator to a digital hybrid spectrometer. Enhancements none for full bandwidth continuum none for highest resolution Wider bandwidth--get 32 x increase in resolution. Other modes up to a factor of 32 increase in frequency resolution many obs will use 4bit correlation; also more oversampling modes Benchmark performance Baseline --64 to 256 lags, latter for 1 BB per quadrant Enhanced -- 2048 to 8192 lags, latter for 1 BB per quadrant Subband seams are a problem. To combat this would use fewer subbands--say 8 rather than 32. Or one can choose any combination of the n subbands--ones which happen to include interesting spectral lines, for example. One cannot steer the subbands to center on those lines, however. 4096 total tap weight multiplications. Two sets of tap weights stored for rapid band switching.*

*Also straight through mode. Problem--no mechanism to prevent aliasing at subband boundaries except for steep boundaries of the filter. Modes. Solution is to make as few seams as possible still giving the desired resolution. LD: Increasing the clock rate to 129 MHz would completely eliminate this problem. This is a 32/31 increase. RE: This would be a huge change to the existing change.*

Comoretto and Baudry: Tunable 2 stage FIR Filter Option *Advantages--2048 channels at full polzn. zooming in on selected spectra regions broadband and high resolution simultaneously.*

*Overlap subbands by a few channels to increase spectral accuracy dramatically. Lose some bandwidth--93% of 2 GHz left for example. Can be done with polyphase filter only with change of clock rate. Near band edges, in addition to amplitude problem, there is a phase problem also--the phase, whatever it is supposed to be, is forced to zero. This can be solved with a tunable digital filter. Twice the multiplications in Ray's design but there is more significance, so complexity is higher. Reduced bandwidth options--second filter can produce decimated output at reduced bandwidth 62.5 MHz down to 7.81 MHz. Needs to be studied in its interaction with station card. All 32 independently tunable in width as well as position. Baudry--hardcopy design lower power 40% cheaper better performance 70% size reduction 18-20 weeks to quantity production; 12 weeks or so to first one. Question--are the residual phase closure errors at the edge of the band severe enough to damage the imaging. One can overlap more to reduce this. One probably never loses more than ten percent of the total band, 5% at each end. Basically, as the signal passes through the band edge an aliased feature appears in the next subband whose phase is flipped 180d from the first signal, averaging to zero. Highly desirable to have downloadable tap coefficients for the second stage. BC thinks there would be no problems at the stitch points as long as the power was matched. Long discussion--delays etc can be built into the filter. The filter does have a passthrough mode; if we do that then we have to wake up the tracking in the other part of the system (station card?). HH: Going to tunable filter are we introducing another set of artifacts, different but comparably worrying--must meet the spec to have 40dB suppression. Goal was 50dB and it seems this meets the spec. Schedule from Altera. Could receive parts in Oct 04 if design in hand by May 04. Prototype with FPGAs in May 04 would give five months before hardcopy chips in Oct. Production boards by May 05. For stitching how often does power measurement need to be made--BC every cross correlation time. LD: These changing thresholds are like an ALC. This isn't part of the ALMA design and needs to be thought through. Probably don't need to do the power measurement EVERY cross correlation time. Data rate--limits data coming out. Sensitivity--cannot at full bandwidth get full four bits out but in narrower bandwidths one can do this. This will be a feature of the enhanced tunable filter. Just tune two LOs to same frequency, use two two bit quantizers; only in a narrower bandwidth are these available. Station card will need FPGA redesign, backend software, backplane owing to voltage different Power card change for new voltage. Schedule would be filter delivery and new software, the latter probably hardest.*

Lunch.

Discussion

*RE: Request to make FPGAs somewhat larger than necessary for the first filter cards to accommodate perhaps something extra. RC: When is the drop dead date? RE: We'll have a small number of original filter cards so we can test next year. Probably no problem getting many more filter cards needed; at least the early science array could use these if necessary. Decision 4thQ 2004. Software would support a minimal number of modes with the old filter. Although writing the software is difficult it is more difficult when the needed resource (hwe experts) is overseas. MT: The tunable filter is a proposal of the correlator IPT. The committee recommends, the Change propagates and is commented by the various IPTs before becoming ALMA policy. I am attending this meeting because I wish to get through this Change as rapidly as possible. BC: First stage 8 bits, 9 bits second. This sets the system dynamic range. 8 bits seems a bit thin one should implement Ray's request to use a larger FPGA and test; 10 bits would work much better. The EU group should carefully consider the number of bits coming out of the lookup table. Subband stitching has not been investigated with power measurements, truncation, etc. The committee recommends such a memo be produced within two weeks or so. Including self-power. LD: With autocorrelation there is still a little bit of aliasing remaining. This was not a driver for eVLA and hence not thoroughly investigated by BC. BC:  $10^4$  dynamic range; all the aliasing may produce a signal which sneaks above this. Ten bits better.*

Science requirements

*Power in spectral lines no problem in a 2 GHz filter but with the narrower filters this may be a problem. Science IPT should supply the strength and width of the strongest expected line so that the Correlator IPT could ensure that the dynamic range spec is met. The loss spec should be (1-.88) 2bit correlator. This needs to be multiplied by 0.985 loss for the filter (or whatever). So the spec should be 0.12 relative to perfect (no losses) rather than relative to some unspecified standard. CH: There are other requirements. These should be addressed. JW: Tell me what they are; give me the compliance matrix and I will fill it out (leaves room). MT: SE to supply Correlator IPT with list of approved documents to be complied with. Correlator IPT responds. SE should supply compliance matrix. JW agrees. BC: CDR guidelines. Software which produces the design should be archived as well as the design. JB: Training? Part of Ops documents which are not yet done? JW: Yes. BC: Recommends elevated temperature testing--40C over a weekend. In the downconverters the 2 GHz bands can be moved in frequency to stitch together; they go through different samplers so there may be a level problem. MT: Please put everything in the report, even if unpleasant. We may not follow all you advice but we would like to receive it all, good bad and ugly.*

Discussion. *Baudry--optical crossbar switch. Not necessary with enhanced filter, so should be mentioned in the report. It is in the plan but unfunded; not needed with new filter. Committee notes that the tunable filter obviates the need for this. Bolyard--training program and ops procedures. Me--I feel that the correlator meets the science requirements. I can't think of any other ALMA system in which I have more confidence. The tunable filter goes some way toward fulfilling some 2GC requirements. Approve the*



*baseline filter card but recommend pursuit of the tunable filter. I'll need to collect Science IPT, ASAC comments so a list of modes with tunable filter; examples, including four bit examples. How fine does the resolution get? The science possibilities enabled by the tunable filter are varied and exciting; the Science IPT can provide specific examples. Given estimates of expected phase errors at subband bounds, Science IPT will attempt to calculate the effect of these on image fidelity. What modes are implemented on the prototype correlator? What are plans to calculate the digitization corrections? Dynamic range action item. Langley--notes the -48V standard; his card has +48V but is isolated. Scott--tunable filter great; stitching be done in CDP then smoothed and decimated to correct data rate. Porter--happy to be on committee. Compliance matrix is important in antenna contracts. We need a standard list of what goes into this matrix. Haupt: Exceptionally good work. Change request for tunable filter. Supply power supply manual to SE. Parts list for board to SE. Mechanical analysis for earthquake risk.*

*HH: Impressed with good job done. Reliability and margin checks--not much enthusiasm for doing this. T and V margins. JW: Could runs these chips at 2.5V and get 250 MHz performance; we're doing lower values to extend lifetime. Most agree on temperature testing, some feeling that voltage changes not so important. JW: Please be specific. HH: dynamic range spec really met with each configuration? JW: CorrIPT wants value for max bit error rate for transmission to x correlators. Also template of requirements list, in addition to science. BC: Testing under warm conditions important--shows failures. 48V DC wire color coding should be consistent throughout ALMA. Report available in draft form in two weeks. List of recs and action items.*

Short report for design team and attendees at large.

*Rec project adopt tunable filter, recommend project work on details, budgeting, schedule all consistent with L1 Milestones then decide upon incorporation into project. Change request details consequences for project in all respects/IPTs.*

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**Meeting Agenda****Thursday, 2<sup>nd</sup> October 2003 NRAO Charlottesville Technical Center Auditorium**

<b>0800</b>		<b><i>Southern Style Breakfast</i></b>	
0830	15 m	Welcome and Charge to Committee	<i>M. Tarengi / D. Emerson</i>
0845	15 m	CDR Requirements and Process	<i>B. Carlson</i>
0900	20 m	Science Requirements	<i>A. Wootten</i>
0920	40 m	Architectural Overview	<i>R. Escoffier</i>
<b>1000</b>		<b><i>Morning Break</i></b>	
1015	15 m	Digitizer status	<i>A. Baudry</i>
1030	15 m	Fiber Optic Tx/Rx Status	<i>C. Langley</i>
1045	15 m	Filter Functional Description	<i>R. Escoffier</i>
1100	20 m	Signal Interfaces	<i>R. Escoffier</i>
1120	20 m	Station Card	<i>R. Escoffier</i>
1140	35 m	Correlator Chip and Correlator Card	<i>J. Greenberg</i>
<b>1215</b>		<b><i>Lunch</i></b>	
1315	30 m	Long Term Accumulator and Final Adder	<i>C. Broadwell</i>
1345	15 m	Control Cards	<i>R. Escoffier</i>
1400	30 m	Control and Data Acquisition Software	<i>J. Pisano</i>
1430	30 m	Power, Site Interface, Safety	<i>J. Greenberg</i>
<b>1500</b>		<b><i>Afternoon Break</i></b>	
1515	15 m	Environment and RFI	<i>J. Webber</i>
1530	30 m	Schedule and Budget	<i>J. Webber</i>
1600	15 m	Production Facility - New Laboratory	<i>J. Webber</i>
1615	15 m	Production Plan	<i>R. Escoffier</i>
1630	30 m	Installation, Operation, and Reliability	<i>R. Escoffier</i>
1700	30 m	Discussion	<i>B. Carlson (Chair)</i>
<b>1730</b>		<b><i>Meeting Adjourns</i></b>	
<b>1830</b>		<b><i>Evening Reception</i></b>	<i>C &amp; O Restaurant</i>
<b>1900</b>		<b><i>Dinner</i></b>	<i>C &amp; O Restaurant</i>

**Friday, 3<sup>rd</sup> October 2003****Ivy Road Central Development Laboratory**

0800	60 m	Hardware Examination	<i>All</i>
0900	10 m	In transit to NCTC Auditorium	<i>All</i>
		<b>NCTC Auditorium</b>	
0910	30 m	Single and Polyphase Filter Options	<i>R. Escoffier</i>
0940	20 m	Tunable Filter Option	<i>G. Comoretto / A. Baudry</i>
1000		Southern Style Breakfast Break	
1015	105 m	Discussion of Filter Options	<i>R. Escoffier (Leader)</i>
<b>1200</b>		<b><i>Lunch</i></b>	
1300	120 m	CDR Requirements Review and Discussion	<i>B. Carlson (Chair)</i>
1500	150 m	Committee-only Discussion and Report Writing	<i>B. Carlson (Chair)</i>
<b>1730</b>		<b><i>Meeting Adjourns</i></b>	