Considerations on an ALMA array containing dissimilar antenna elements

A Report from NRAO's ALMA Technical Advisory Committee (ATAC)

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There is a proposal that ALMA might be constructed with two different antenna designs – 32 antennas of one design, and 32 antennas of an alternate design. Both designs of antenna would be identical in aperture, and meet the same specifications. The ATAC has considered this concept from from the technical standpoint, and concludes that, while the array could probably be made to work with such a concept, it will be more costly and is likely to result in reduced array performance.

Concerns:

1. Common mode phase errors.

Many effects, especially in the interferometric phase, cancel out to a high degree when you have identical antennas. This applies to motion of the effective antenna phase center as a function of temperature and of gravity (different elevations), but also to some extent from wind too. The characteristic of wind at Chajnantor is a strong steady component, with fluctuations superposed. The steady component will affect identical antennas in the same way.

The arrangement of modules in the dissimilar receiver cabins is likely to be somewhat different in different antenna designs. In itself, this is only a minor nuisance, however the air circulation will be different and the operating temperatures of various modules mounted in the racks and in the front end assembly are likely to change differently, both as a function of outside air temperature and as a function of elevation. The same applies to runs of cable or fiber carrying the local oscillator signal inside or outside the antenna, from the station connection point to the receiver. All this is likely to lead to phase drifts that are different between two antenna types and so do not cancel.

2. Common pointing errors

From the imaging simulations, identical, even time-varying, pointing errors on all antennas can be corrected for in software (for example, treating the data as many rapid snapshots with different pointing that can then be mosaiced together.) This is much more difficult, and may not be possible, for a heterogeneous array with a mix of pointing errors.

3. Debugging

Debugging a heterogeneous array will be more difficult; the learning curve in identifying and correcting problems with the antenna, and electronics installation on the antenna, will be twice as long.

4. Software

Although the control software interfaces will presumably be similar, they are unlikely to be identical – the Vertex and AEC antennas already have fairly different ICDs. Different software will be needed - certainly different pointing models and higher level software to cope with having antennas with different performance characteristics, but real time controls will inevitably be different. This means extra development and extra maintenance.

5. Operations, Maintenance and Spares.

Twice as many spare parts will be needed, and an antenna maintenance crew will need to be trained twice. This goes for initial antenna adjustments as well as long-term maintenance.

6. Imaging quality, polarization

The sidelobe patterns of the antennas may be different – this depends mainly, but not exclusively, on how different the feed leg and Subreflector blockage is. All the imaging studies so far have assumed identical antennas; it is possible, although not certain without further study, that high dynamic imaging quality may be compromised.

7. Contract, cost

A lower cost, per antenna, is almost certain to be obtained by placing the contract (or even with the expectation of doing so) for 64 antennas rather than for 32.

8. Transporter, antenna pads

The transporter and antenna pads will need to be designed to accept both types of antenna. How difficult this is depends on details of the designs of both, but inevitably the design will involve higher cost if it is to be compatible with two different antenna designs. The local oscillator phase drifts may also be different at the antenna pads, mainly because of different cable or fiber routing, contributing to the effects already mentioned in **1** above.

Conclusion

ALMA can be made to work with dissimilar antenna designs, but probably not so well, and with more effort and cost.

ALMA is pushing the state of the art in many areas, in particular in the phase stability needed at high frequencies in order to achieve high dynamic range. Having identical antennas helps a good deal, because many interferometric errors will cancel out, and identical pointing errors can be allowed for in software. Even so, and even with identical antennas it is questionable whether the very demanding requirements of the array will be met. Losing the advantage of some errors canceling out, because of the identical antennas, will make it that much harder to meet our very demanding requirements.

There is a hidden cost of having two different designs; more spare parts, more expensive transporter & antenna pads, and extra cost in training maintenance personnel. More effort will be needed in debugging the array, characterizing the antennas, and in real time control and data analysis software. It will be that much harder to bring up a working array, with more manpower (scientists & programmers) required.

Building an array with dissimilar elements will compromise the performance by negating the common mode, error canceling advantages inherent in interferometers using identical antennas, and will increase the work involved in commissioning and maintaining the array. In the end, ALMA would be a poorer telescope.