ALMA Memo 405
Unaddressed Issues for ALMA Configurations

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Abstract

I am reminding the configuration designers about a few issues which have apparently been put aside while more important issues were being addressed. These include the requirement of multiple compact configurations to adequately cover the entire observable declination range, the design of other N-S stretched configurations for extreme declination sources, and possibly a global N-S elongation factor for the base configurations. Addressing the need of multiple compact configurations for extreme declination sources, which is required for the observation of about 30% of the sky visible from Chajnantor, will likely add more antenna stations to the configuration design.

1 Introduction

The configuration designers have made a lot of progress, and I think the concept of low sidelobe, incrementally reconfigurable arrays with a naturally tapered (u,v) distribution is an excellent choice (Recommendations of the Configuration PDR, 2001). However, while we are currently approaching the panic of figuring out where to pour concrete, a number of secondary configuration issues which affect some details of pad placement seem to have been forgotten. This short memo serves to remind before it is too late.

2 Compact Configuration Issues

The compact configuration will usually be used for mosaicing. The most recent design of the compact array has been driven the optimization of surface brightness sensitivity subject to the constraints enforced by the transporter and roads (Kogan, 2001).

We need to ensure that the requirements of good mosaic imaging are being met by the design of the compact configuration. If the ACA were to be built, the requirements on the compact array would be somewhat relaxed. However, without Japanese partnership, we don't know if the ACA will ever be built, and we must at this point ensure that our compact configurations will permit quality homogeneous array mosaicing over the full range of observable declinations.

Mosaicing places two competing requirements on the compact configuration: the antennas must be close enough to effectively obtain short spacing information indirectly via the Ekers and Rots scheme, and the antennas must be far enough apart so that they do not shadow each other (Holdaway and Foster, 1996). It is not difficult to come to a good balance between these two requirements for a single declination, but it is quite difficult to achieve a good balance for all source declinations. Hence, homogeneous array mosaicing pushes us toward multiple compact configurations optimized for different ranges of declination, and quite likely three different compact configurations will be required. One compact configuration will be optimized for observing around the zenith (say down to 45 degrees elevation to the north or south), a second compact configuration will be stretched more in the N-S direction, optimized for observing at more extreme declinations (say down to 25 degrees to the north or south, but short baselines in the E-W direction will not permit low elevation observations far away from transit), and a third compact configuration will be optimized for observation of the most extreme declination sources. This is all speculation at this point, as none of these issues have been investigated in detail since Kogan produced his new compact configuration, which would be considered the starting point for the zenith compact configuration.

We may be able to make parts of the extreme declination compact configurations by combining the zenith compact configuration stations with the inner stations of the spiral configuration, but given the less-compact nature of the spiral arms, we will likely need additional stations. While the extra expense of these stations will likely irritate people working on the budget, they are a necessity for low and high declination mosaics (possibly 30% of the sky visible from Chajnantor), and will make a much smaller impact on the budget than the ACA would have.

Once we have a set of compact configurations, we should proceed with an "all-declination" mosaic simulation campaign to verify that we have the whole sky covered. This process will take some amount of iteration (ie, some declination range may not be well imaged, requiring configuration adjustments and another round of simulations), and we have little time for the iterating.

3 Hybrid Configurations

While we are on the subject of stretching the compact configuration in the N-S direction for extreme declination sources, we should look into making hybrid configurations stretched in the N-S direction for observing extreme declination sources with all the array configurations. (The name "hybrid" comes from the VLA. When moving from the 35 km A configuration to the 10 km B configuration, the E and W arms ar moved first, leaving long spacings on the N arm. When seen in projection from a southern source, the north arm is foreshortened and the array produces a more circular beam. We use "hybrid" in the same sense, as a cross between two arrays of differing resolution, to obtain longer N-S baselines for extreme declination sources.) Such stretched configurations will provide a more nearly circular beam for extreme declination sources. However, given the incremental reconfigurability of the array, these N-S stretched hybrids will likely not make a major impact on the beam elongation for extreme declination sources unless more extreme N-S oriented pads are occupied out of turn. This would require depopulating them again to get the next larger array with a circular beam at the zenith.

So, we must specify a plan for hybrid arrays, detailing the operational aspects of that plan, and quantifying the improvement we get for sources at various declinations.

4 A Global Stretching of the Configurations

Back in the days when the MMA was conceived of as concentric ring configurations differing in size by a factor close to 4, the concept of hybrid arrays was not as attractive as it is for a system of filled configurations such as the three-armed spiral. So, it was supposed that one could calculate an optimum N-S stretch to apply to the ring configurations to make the beam most nearly circular for all observations over the sky. In order to do this, one needs an observing strategy, as zenith snapshots and horizon to horizon integrations give very different answers (at extreme declinations, a circular array would result in a highly elongated beam for a zenith snapshot, but as the array moved around in projection against the source in long integrations, the beam would largely circularize).

Foster (1994, ALMA Memo 119) investigated the optimal elongation for the "A" (ie, 3 km, the largest) MMA configuration. With its low surface brightness sensitivity, it was supposed that this array would mainly perform long track observations, and at each declination, the limiting hour angles were chosen such that the airmass was no more than 40% higher than the airmass at transit. This exercise, performed for both Mauna Kea at 20 degrees latitude and South Baldy at 34 degrees latitude, lead to a north-south elongation of 1.1 resulting in a most nearly circular beam integrated over observations over the whole sky. Tighter hour angle limits which result from a 20% higher than transit airmass lead to an elongation of 1.2.

Currently, there is little leadership and less consensus concerning a stretching of the configurations. I think that we need a design for hybrid arrays and an understanding of how much they will help before we can make a call for stretching the entire spiral array pattern in a N-S manner. Consequently, a decision to introduce a global stretch to the set of configurations would impact the strategy for the hybrid arrays.

5 A Strategy for Multiple Configuration Observations?

We will never come to a definitive strategy for combining data from multiple configurations. We do have one very good principle that has helped guide the design process: we should aim for good single configuration imaging. This does not mean that multi-configuration imaging should not occur, just that single configuration imaging should be possible much of the time. While this principle enforces good short baseline coverage in all configurations, it has also been a primary factor in choosing which configuration design is best in that many of the simulations were probably dominated by the details of the shot baseline coverage.

There will be many reasons why multiple configurations are used, and each will have its own strategy:

1. The scientific goals of a project evolve, requiring higher resolution data after the first low resolution observations have been analyzed; why not add in the lower resolution data to improve the image and SNR? This case will be fairly common.

2. Go to a small configuration briefly because the configuration with the desired resolution didn't have enough short baselines. With 64 antennas and a good range of baseline sizes, this situation will not be as common as for the VLA. Maybe it will occur 10% of the time?

3. To image a very bright complex and large object in its full glory, multiple configuration observations will be the best way to proceed. With 64 antennas and a good range of baseline sizes, this situation will not be as common as for the VLA. Maybe it will occur 10% of the time?

For a strawperson strategy for the third case, I suggest:

- Adjacent configurations used for observing should have a minimum factor by which their resolutions differ (ie, a factor of 2 or 3 or 4).
- The time spent integrating in the different configurations should be related to the maximum baseline B_{max} of each configuration. For example, to equalize the density of (u, v) samples in the Fourier plane, the time spent in each configuration would be proportional to B_{max}^2. This leads to very long integrations in the bigger configurations, and is probably not what we want to do since we are not aiming at uniform (u, v) coverage anyway.
- The combined data should be uniformly weighted (or probably better, Briggs weighted with a bent toward uniform), so that regions of the (u, v) plane that have data from more than one configuration are handled optimally.
- Uniform weighting will mess with a naturally tapered (u, v) distribution. Hence, we should reestablish the taper by manually tapering the (u, v) data. This will result in a minimum of noise increase.

Do we need to progress on a strategy for multiple configuration observations? Will such a strategy buy us anything at this time? Probably not, as there are no plans to optimize the different configurations for any sort of multiple configuration observations at this time. But we've discussed such such a strategy in the abstract many times, and I thought it would be good to put down something more concrete on the chance that it may influence someone's thinking in the future.

References

Recommendations of the Configuration Preliminary Design Review, *http://www.cv.nrao.edu/ awootten/mmaimcal/configurationpdr.html*

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