NLSRT Memo No. 23

From: CVAX::ABRIDLE 5-DEC-1988 12:39
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Subj: My reaction to Dec 2/3 meeting

Here are some observations and conclusions based on what I heard at the Dec 2/3 meeting at Green Bank.

A. Array vs Single Dish

The advantages of an array are:

1. Can provide large total aperture without the structural design innovation needed for equivalent monolithic antenna. This dominates choice if the required total aperture much exceeds equivalent of 100-m diameter.

2. Reduces pointing problems, wind loads for given final resolution.

3. Small elements might use conventional offset-feed geometries to minimize aperture blockage and get very clean primary beam.

4. Can place some control of beam shape in hands of observer.

Tradeoffs are about even on:

1. Speed, and complexity of electronics, for large-area surveys (if the single dish uses array feeds for such work).

2. Initial construction cost (at about 100-m effective aperture); dish needs more structure, array needs electronics and computing. Much above 100-m aperture, array should win easily because dish requires pioneering design.

3. Self-calibration of atmosphere. Dish must have array feeds and a large correlator; array has what it needs anyway. Techniques are better developed for arrays, but principles are well understood for dish also.

4. Both can provide high surface brightness sensitivity and zero spacing data if all auto and cross correlations are used in the array.

The advantages of a single dish are:

1. Can keep electromagnetic path very clean by dismounting all unwanted receivers and feeds whenever it is important to have low sidelobes, little stray radiation and RFI, flat spectral baselines. Array elements get cluttered in practice because there is operational pressure to leave equipment for all wavelengths in place on all elements all the time.

2. Can make better use of state-of-the-art receivers, i.e. can run with prototypes and/or devote all maintenance resources to keeping a small number of packages in tip-top shape. Faster response to innovative receiver design is possible.

3. Re-engineering of feeds and receivers is much cheaper because there are fewer of them.

4. Can be maintained and operated by less people, as there are fewer item to be maintained and attended to.

B. RFI performance

Green Bank's "trump card" as a site is the Quiet Zone, and much of the exciting low-frequency science (high-redshift HI, multifrequency pulsar work, etc.) requires exemplary RFI rejection capabilities. We should plan eventually to do whatever we can toward interference excision by signal processing. But we must get off to the best possible start by emphasizing RFI performance and primary beam cleanliness in the design of the antenna(s). The RFI environment will only get worse with time, so we must invest as much as possible now in design that will reduce far-out sidelobes.

The enormous generic advantage of interferometers for RFI rejection is based on fringe rate and delay discrimination. These advantages vanish asymptotically for compact arrays, though some use can still be made of them in practical finite arrays if the RFI is impulsive.

The worst RFI signals are from satellites, against which very clean beams are needed as the first line of defence. An array of small elements could use offset-feed technology to maximize clear aperture and so minimize RFI acceptance through far-out sidelobes. But an extremely compact array might negate this for much low elevation work because of aperture blockage and scattering off adjacent dishes. RFI rejection would be best for a not-too-compact array of offset-feed dishes working near the zenith, or at azimuths and elevations for which blockage had been specially optimized (e.g. as one might do for the Galactic Center).

It will be difficult to use offset-feed technology for apertures of order 100m, except by illuminating off-axis sub-apertures from an on-axis minimum-blockage feed support (as was proposed for galactic HI work with the 300-ft before its demise). A new single dish should minimize use of massive feed supports, and perhaps maximize use of non-conducting guy wires with dielectric constants as close to unity as possible (are there any suitable strong materials ?) The single-tower geometry used on the Jodrell bank MkI, and the two-leg+guys geometry used on the 300-ft are preferable to a tripod or tetrapod, and modern versions of these should be considered.

A compact array would keep all the feeds closer to the ground than would a conventional dish with the same total aperture. This protects against local sources of interference getting directly to the feed, which may be an important problem at the lowest frequencies. The main RFI disadvantages of a compact array are dish-to-dish blockage, scattering and cross-talk. Most practical compact arrays (e.g. VLA D-array) have severe cross-talk problems, but none was aggressively designed to reduce this. We should be sure that we know how to eliminate self-interference before committing to a ompact array.

C. Designs we should elimate now

The scientific goals presented at Green Bank ask for large apertures at low frequencies, but significant residual aperture at 3mm. I think we should therefore eliminate the following options:

1. A single 70-m class antenna going to 3mm. This will be too small to do exciting science at the low frequencies for which the Quiet Zone is an ideal location.

2. A large-aperture array of many cheap dishes operating only to 5 GHz, e.g. off-the-shelf cm-wave communications antennas. This will be cheap to construct but relatively expensive to operate, and will not service the high frequency applications.

3. A single 100-m class antenna with a conventional off-axis feed geometry. The feed tower will be prohibitively tall if the path lengths from to the dish are equalized enough that the dish can be illuminated satisfactorily by a broad-band feed with a reasonably symmetric beam. We should however remain open (for a while) to suggestions for clever geometries that would reduce the tower height without exacerbating the illumination problem.

D. What's left ?

Two possibilities occur to me:

1. An inner-panel, outer-mesh dish giving 100-to-130-m aperture at low frequencies and about 70-m aperture to as high a frequency as we can afford. We should shoot for useful performance at 3mm, but back off to 1 cm if this cannot be done at reasonable cost. The dish should have an on-axis but minimum-blockage design; we should plan to support optional slightly off-axis feeds to illuminate a fully clear sub-aperture for work that requires the ultimate in sidelobe suppression.

2. An array with one (central) element that operates up to 3mm and a surrounding ring of about 6 equal-sized elements that operate only up to about 5 GHz. The outer elements might be off-the-shelf communications antennas, and would not be used for the highest frequencies. The ring might be made reconfigurable to meet the blockage and resolution requirements of different experiments. The element size should probably be about 40-m. Possibly we could use an offset feed clear-aperture design at this diameter.

I suspect that the array would be more scientifically flexible for a given construction cost, but that it would cost more to operate, and to keep equipped with state-of-the-art receivers, in the long run. If it was provided with a "generous" computer capacity at the outset, the computer might also contribute significantly to the VLA/VLBA computing problem, and thus give Green Bank an extra role as an array computing center.

I marginally favor (1) because it would be cheaper to operate as a state of the art instrument, and so might be a better "matched filter" to the likely budget. But array options deserve a further hearing in-house, at least for a few more weeks.