NLSRT Memo No. 26

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To: KKELLERM
Subj: Very slightly revised LSD memo

Memo:

Subject: Thoughts on the replacement for the 300 ft. telescope.
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300 ft. replacement: a closely packed array of smaller elements

The arguments in favour of building a single, large dish are summarized as:

1) A large collecting area is available, particularly important for pulsars and other confined objects where the highest possible sensitivity is required.

2) High sensitivity to low brightness extended emission. Synthesis instruments perform notoriously badly in this respect. High sensitivity to extended emission requires that the collecting area be centrally concentrated, rather than spread thinly in the UV plane.

3) Capability of mapping low brightness objects over a very extended field. Most synthesis mapping to date has been limited to one, or at most a few, primary beams. We need an instrument able to map much larger fields.

4) Versatility. With a single dish, only one (perhaps two) receivers are required per waveband, and it is much easier to build quickly a single new receiver for the single dish, than to outfit a multi-element array, should some new discovery unexpectedly make a new frequency band important

I suggest that in all above respects, an antenna consisting of a number of smaller elements, phased together, will actually produce higher performance.

1) Sensitivity to confined sources (pulsars, etc.). This just goes as collecting area. The smaller elements would be phased together to produce a single i.f. . A single backend (de-disperser etc.) will suffice for the complete phased array. More collecting area is likely to be possible with a number of small antennas, than with a single element (money, engineering problems of huge structures, wind, gravity etc.) It is assumed that the cost of building a dish of diameter D increases faster than the square of dish diameter.

2) An arrangement of closely packed antennas, using the zero-spatial-frequency responses (i.e. total power) as well (perhaps) as the cross-correlation terms, will have at least as good a sensitivity as a single dish of the same collecting area, but will have a potential observing efficiency advantage because of the additional multiple-beaming (synthesis) possibilities. Some thought needs to be given to the design such that the effect of shadowing of adjacent dishes is minimized. Because the auto-correlation components will be used as well as the cross-correlation terms, there will be o absolutely no compromise in measurments of structure more extended than the individual primary

beams. Spatial frequency terms corresponding to baselines greater than a dish diameter but smaller than the gap between adjacent dishes would be attenuated, so the separation between elements should not exceed twice the dish-diameter. This should easily be realizable, with minimal degradation from shadowing at low elevations.

3) (a) Phasing a number of smaller elements together to produce a single beam, which can be scanned both electically and mechanically, will provide excellent large-scale imaging capabilities. There is much more control over the effective beam shape, and algorithms such as CLEAN will work even more effectively (due to the better UV sampling) than on the VLA. In practice, several simultaneous "single beams" will be available.

(b) Treating the collection as a more conventional synthesis instrument, but using auto-correlation as well as cross-correlation terms, large scale mapping will be possible using the techniques already being developed for the MMA.

The phased elements will produce SIMULTANEOUSLY mapping beams corresponding both to the individual element primary beam and to the synthesis beam of the whole array.

4) Since the antenna will be used at relatively low frequencies (~< 50 ?) the problem of maintaining high performance receivers on a relatively large number of antennas is relatively trivial. (!) This is not true at higher frequencies. Today's generation of low-frequency receivers are relatively simple, broadband, and virtually noiseless.

5) Reliability. If one of the individual elements fails, then the effect on the overall performance of the system is minimal - just a small fractional decrease in total collecting area. If one element from a conventional synthesis array fails, the effect on UV coverage is much more serious, and of course if a receiver on a single large dish fails, then the whole system is down.

6) Should there be a desire to go for higher frequencies (say 70-115 GHz, or even just the 30-50 GHz band), this can be achieved more practically with a number of small, high-precision dishes than with one, huge, high-precision dish.

7) It would be practical to extend the collecting area of this closely-packed array, at some future date, simply by adding more dishes. Clearly the collecting area of a single, huge dish could never be increased beyond the initial design.

Conclusion:

It seems to me that in every aspect of performance that would cause one to chose a large single dish, a phased array design would be superior to a single large dish. The array should be designed at the outset for high sensitivity to extended structure, and NOT, as is the case for all existing arrays, for high resolution.

e optimum number and size of the individual elements is an gineering choice - e.g. 16 VLBA-type elements would give double the llecting area of a 70-meter dish, but probably 25-m is not the optimum diameter.

There is NO compromise in performance with this closely-packed array, compared with a large single dish. The techniques to be devloped for this (large scale mapping algorithms, multi-channel correlators) will in addition contribute to the future MMA.

It will, I believe, be possible to obtain a larger collecting area for lower cost, in a shorter time, with a much higher upper frequency cut-off, with an all-round superior performance, if a closely packed phased array is constructed in preference to a large single dish.