Memo 13

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Choosing Offset Gregorian Optics for the SKA/TDP Prototype Discussion Summary and Rationale

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INTRODUCTION

The Antennas Working Group met in May, 2009 to review and plan TDP antenna research. One of the leading topics at the meeting was how to achieve the goal of an installed SKA/TDP prototype antenna by 2012. It was quickly agreed that achieving this goal would require an accelerated timeline of design studies and decision making. The actual process of detailed design, selection of fabrication methods and fabricators, construction, assembly and installation will take at least two years. This emphasizes the need for making a final choice of basic optical and mechanical design in 2010. Given the limited number of people available to perform design tradeoff studies a preliminary decision was taken to focus on offset Gregorian optics for the SKA/TDP prototype antenna. This short document is intended as a summary of the reasoning for this choice and a stimulus for discussion leading to the final confirmation of offset Gregorian optics for the prototype.

The reasons for this choice can be roughly grouped into three categories, technical, financial and programmatic. Naturally, the technical aspects are the most involved and can be further subdivided into two categories. The first being direct support of the science goals: the proposed offset design type offers better specifications in support of key science goals. The second technical subcategory is antenna performance versus cost. Most significantly, offset designs have the capability of providing lower system temperature which trades directly against the total number of antennas and hence system cost.

The financial justification is relatively simple, the cost of offset designs is higher than simple prime focus antennas but only a modest multiple on the order of 1.2 to 1.5. This increased cost can be partly to totally justified by the improved noise temperature alone. Another financial consideration is computing cost. A lower number of higher performance antennas would reduce this part of the total system cost as well.

Programmatic considerations consist of how this prototype fits into the pantheon of other antennas being constructed by SKA pathfinders. Offset Gregorian optics are different from the symmetric antennas being built for the Australian ASKAP and South African KAT7 projects and will provide another data point of performance and cost.

Technical Justification – Key Science Goals

The proposed offset optics provide a clear optical path and aperture which has the advantage of not scattering any of the radiation out of the

focused region. With proper design this can lead to very low sidelobes away from the main beam and its first few sidelobes. Achieving this in practice also requires minimizing spillover and edge diffraction which can scatter energy to wide angles. Reducing the illumination intensity at the edges of both reflectors reduces these factors but has the tradeoff of reduced aperture efficiency. Dual reflector shaping can ameliorate this tradeoff but will degrade off axis performance and perhaps low frequency performance.

The very small wide angle sidelobes from a good offset design reduce the received levels of strong sources out of the field of view, enhancing high dynamic range. They also provide enhanced rejection of RFI, especially from satellites. RFI from satellites will be a growing problem which will not be not mitigated by radio quiet zones.

Technical Justification – Cost Reduction From Enhanced Performance

The design factors which produce the low sidelobe levels: clear aperture, low spillover and edge diffraction all reduce thermal noise pickup. The resultant lower system noise temperature increases G/T and reduces the number of antennas required to achieve system sensitivity goals. Maximizing this benefit requires low noise receiver systems. Research on low noise receivers is underway in many locations and not just for the SKA. Future developments in low noise technology may well provide even better receiver temperature, making the investment in low noise antennas even more valuable.

Financial Justification – Cost Differential

At first glance, rotationally symmetric antennas and offset antennas look very different. However, many of the subsystems in each are very similar or at least analogous. The mount is the most obvious example of this. It is virtually the same regardless of what type of antenna it supports. Comparative study of subsystems leads to the conclusion that there is not a large cost difference between the two types. Such a comparative study was done during the early design stages of the GBT. The differential in that case was estimated at about 1.25. [1] That differential included the cost of making one-off asymmetric panels and an entire substructure to transfer the panel attachments to the main load bearing structure. The SKA antennas will most likely be single piece reflectors so once the required molds are made there is essentially no premium for asymmetric reflectors. Given the modest increment in cost and a significant improvement in performance, the total system cost

might well be less with offset antennas even though their unit cost is higher.

Programmatic Justification

There are other projects building SKA pathfinder antennas, the ASKAP project in Australia and the KAT7, MeerKAT project in South Africa. The ASKAP antennas are a prime focus rotationally symmetric design designed to accommodate a phased array feed. These antennas have a third axis rotator which keeps the antenna pattern fixed on the sky in the manner of an equatorial mount. The rotator keeps a wide angle strong source from producing a time variable signal which is difficult to remove from images. The South African KAT7 antennas are a more typical prime focus, circularly symmetric antenna. Both of the these projects will provide cost and performance assessments which will be compared with the SKA/TDP prototype. From a tradeoff / comparison viewpoint it makes little sense to build an antenna which is similar to antennas being built elsewhere.

Conclusion

There was a strong consensus at the AWG meeting that offset Gregorian optics were the choice for the TDP/SKA prototype. If there is to be any discussion of this choice it should occur very soon. If the prototype antenna is to be available for testing in 2012 design efforts must move forward immediately

[1] NLSRT Memo 51, "A Study of Technical Issues and Tradeoffs in the Design of the New Green Bank Telescope", NRAO Technical Study Group, distributed April, 1989