INDIAN PROPOSAL FOR 12m PRE-LOADED PARABOLIC DISH FOR SKA

Reply to "SKA Concept Designs (white papers) -EMT Comments" By P.J. Hall: 1st Oct. 2002.

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1. In this note are given clarifications to various queries raised by EMT on the Indian Proposal of Preloaded Parabolic Dishes of 12m diameter for the SKA. Our reply follows queries raised in various sections of the above report giving comments by EMT. We suggest that EMT may number all the paras in future so that cross reference to the queries raised and replies are easier.

2.EMT SECTION 2

Our General Comments:

2.1. We appreciate comments by EMT that more detailed SKA specifications may be produced by ISAC. The case for wide frequency coverage from about 150 MHz to at least 10 GHz, with clear science-goals and multi-beaming and sensitivity requirements in different frequency ranges needs to be firmed up at an early date.

2.2. As is known that parabolic dishes have the advantage of being able to provide good performance over a wide frequency range. Further, by forming sub-arrays, particularly for many programmes which do not require full sensitivity, several beams can be provided across the sky. Parabolic dishes have also the advantage of providing low noise performance, good polarization capability and a full sky coverage at the selected site. These features are of considerable importance. Regarding RFI mitigation, we believe that it should also be possible to place nulls in the direction of strong sources of RFI at each station of the SKA, since each station is likely to have large number of 12m dishes, say 64 nos. or larger depending on the number of stations in the entire SKA array (say 120 stations). It may be noted that nulling would be more effective, larger the number of antennas at each station.

2.3 The Indian group has now finalized drawings for the mechanical mount of the 12m dishes. We are now planning to place a contract with a firm for manufacturing it and hope to assemble the dish with the drive system and the mount by the end of the year. We plan to do reliability analysis simultaneously. It is also planned to carry out a modal analysis on the assembled dish in order to determine the resonant frequencies of the structure of the PPD dish along with other system parameters such as damping and stiffness.

2.4. RRI group is also investigating various designs for the feeds for illumination of the 12m dishes. At present, development of a wide frequency prime focus feed which is one of a class of log-periodic antennas with a trapezoidal structure having minimum phase centre variation with frequency and highly symmetrical E and H plane patterns is under progress. We would in due course take advantage of the developments being made elsewhere in the world by other radio astronomy groups regarding wideband feeds and low noise amplifiers cooled by pulse tube coolers. RRI team is aiming for obtaining cryo-coolers with few watts thermal capacity capable of cooling down to 77 K.

It may be noted that the phase centre of the wideband feeds being developed for ATA, the feed being considered for the US proposal for SKA and the feed being developed by RRI varies with frequency. There is, however, a design in the literature by Peter Excell (IEEE Transactions on Electromagnetic compatibility vol. 41, no. 4, Nov. 1999, pages 344-349) in which elements of log-periodic antenna are fed independently. Their motivation was to have an antenna which can provide a dispersion free transmission for a narrow electromagnetic pulse for strategic application, thus requiring a common phase centre over a very wide frequency range. Perhaps there are other possibilities for a low cost feed and of optimum performance over a wide frequency range for a parabolic dish.

We note that remarkable work is being done by Caltech and perhaps also the industry regarding low noise amplifiers. Dishes may allow use of amplifier chains with high degree of linearity, which may have a lower degree of intermodulation products in the presence of an adverse RFI environment when using receivers with very large bandwidths as required for SKA than perhaps for the case of the phased arrays. The latter could of-course provide a better nulling possibility but dishes may allow use of cancellation techniques more easily? These aspects need careful evaluation by the RFI group of the EMT (see Appendix 2 of the EMT report).

3. EMT SECTION 3: Page 8

PRE-LOADED PARABOLIC DISH (PPD) ANTENNAS

3.1.Q.1: What are steps required for dish manufacturing to be automated?

Answer :12 m PPD Antenna consists of the several parts which can be automated as described below :

3.1.1. A centrally placed welded hub of 4m diameter with cross-section of 200 mm x 200 mm made of 8 mm MS plates: Manufacturing such pieces is possible by using an assembly line method quite economically, if several hundred or more pieces are required. There are no other welded structural frames in our design which is one of the main attraction of the preloaded dish design. All other parts are bolted.

3.1.2. We require 24 nos. of stainless steel tubes or pipes of about 4.5 m in length (40 mm diameter and 8 mm wall thickness) for the radial members of the PPD antenna and a similar no. of tubes of smaller lengths for the circumferential members: one can buy tubes of an exact length if large nos. are ordered: we have experience of the same for the case of the GMRT. In the 12m PPD antennas there are 4 main types of gadgets which can be mass manufactured easily.

3.1.3. The main problem is to mount 24 radial tubes and then bend them elastically to a pre-determined height. Clamping the tubes to the Hub is straight forward. At Bangalore, we have used a central ring and 24 ropes and turn-buckles and a centrally placed theodolite to do the above job. For mass production we propose either placing fixed jacks at 24 places and to operate them either electrically or by using an hydraulic arrangement. Instead of the jacks, we can have pullers mounted on the roof of an assembly shed erected temporarily near each station of the SKA.

3.1.4. Manufacturing of the panels using stretched wire mesh can also be automated in an economical way compared to the panels of a conventional dish using solid Al. sheet panels, since the former have somewhat less constraints, with RMS of each panel being about 1.5 mm. The stainless steel frames of the panels can be easily mass produced and stretched wire-mesh attached using jigs.

3.1.5. Finally, mounting of the support gadgets of panels and aligning them using a centrally placed theodolite AND then mounting panels can be done using conventional procedure using a centrally placed theodolite. However, we propose using a rotating arm which has been used successfully by us for aligning troposcatter antennas of 45 ft diameter in India with RMS accuracies of about 0.5 mm.

It is proposed to make an accurate log of the required labour and their skills for each of the above tasks at RRI as we plan to disassemble the present dish and transport it to another site near Bangalore early next year and then erect the dish on the drive system and antenna mount which is expected to be manufactured by the end of 2003.

3.2.Q.2: Can the authors quantify further the advantages which lightweight dishes confer in terms of mounts and drives.

Firstly, the PPD dish have a much simpler backup structure, essentially consisting of 24 radial tubes of 40mm diameter joined by equal no. of circumferential tubes bolted at the outer rim and specified intermediate points. Secondly, the panels are made of 6mm X 6mm welded s.s. wiremesh made of 0.55mm diameter wires (we may use 0.8 mm wire in future for operation at higher frequencies). Thus, the solidity or the drag factor of the dish is quite low being about 0.25, in contrast to the value of the drag factor being > 1.5 for a conventional dish using panels made of Al. sheets for the reflecting surface (see Cohen 1964, New York Acad. of Sciences). Thus the PPD antennas are subjected to much lower values of wind forces and wind torques at all orientations of the dish than a conventionally designed dish. Also being much lighter, PPD dishes have a much lower value of inertia which leads to a higher value of the locked rotor frequency of the mechanical drive system.

We may point out that a drive system which is subject to much lower values of wind forces and torques can be designed more conservatively with a much higher degree of reliability.

3.3.Q.3 Can this technique be used for making offset paraboloids?

We have not yet conceived a way of making offset paraboloids using the preloading technique. If offset paraboloids with a wiremesh are considered to have an important advantage by the system engineering group of SKA, we could perhaps propose another alternative economical design than a conventional design. One of us (G. Swarup) is considering use of stretched wire mesh constrained by a grid of rope trusses in a more efficient method than that of the GMRT dishes for an offset paraboloid.

4. EMT: APPENDIX 1.

We have initiated discussions with the US groups regarding designs of the mechanical drive system and also antenna feeds and amplifiers. Preliminary discussions have also been made for combining our efforts for developing suitable parabolic dishes. Some of these aspects will be discussed further at Geraldton.

We may note that the US proposal of using hydroformed 12 m dishes would certainly allow very good performance upto about 20 GHz. However, such antennas would be more expensive than the Indian proposal of PPD antennas. It is not clear as to how the US group is going to transport the 12m hydroformed dishes over large distances of the SKA array and whether a mixture of the hydroformed dishes near the central array and PPD far away would get used for SKA if the parabolic design is preferred by the Science Study group of SKA. These are open questions at present and we hope that EMT would provide a better guideline (e.g. updated specifications and clarifications or possible trade-offs) so that we can put the required thrust in our work.

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