Visit To SAO Submillimeter Array
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I. Introduction

I visited the SAO on the 13th and 14th of March 1991 to find out the status of their antenna design, and to see how they had arrived at their present configuration. The main people I talked to were Eric Silverberg, who is directing the project, Bill Bruckman, who is in charge of the antenna design, and Philippe Rafin, who is doing the reflector mechanical design and analysis. I also talked to Ray Blundell, who is in charge of the receiver group, and Collin Masson who is the project's Technical Director.

II. Antennas

The fixed parameters of the antennas are the number (six) and diameter (6m). The surface accuracy will be 15µm rms, and the goal for the pointing accuracy is 1arcsec. Other design parameters are still fluid. Following the visit of the Scientific and Technical Advisory Group (STAG) in February they made several changes to the design where they felt that the committee's recommendations and criticisms were valid. Originally Silverberg was planning to go out for RFQ's in May, but now it will be August at the earliest, and very possibly later than that.

Their main concerns about the antenna are pointing accuracy, phase stability, and panel design. The philosophy behind the design is to make it as light and stiff as possible. The present aim is to have all eigenfrequencies above 15Hz.

i. General Layout

The antenna has been designed to be as compact as possible to minimise pointing, and pathlength errors resulting from temperature and wind effects. The antenna uses a "bent Nasmyth" optical layout in which the beam is always kept in between the elevation bearings, rather than passing through the bearings as in more conventional designs. The beam is sent down into the receiver cabin which is rotates in azimuth. The size of the elevation bearing has been reduced following the STAG visit, partly because of concerns about stiction and the effect that would have on a servo loop. The backing structure will be mounted on a central hub on the elevation bearings. Elevation drive is through a linear actuator, which they feel will give much more stiffness than a more conventional spur gear drive. One criticism of the STAG group was that the antenna was not balanced in elevation or azimuth, but they will probably do this now, even though it increases the mass and inertia.

ii. Mount

Although they originally considered Carbon Fibre Reinforced Plastic (CFRP), the mount will be manufactured from steel. They will probably design the mount themselves and go out for bids on fabrication to prints. The elevation bearings will probably be mounted on 'A' frame supports which will be inside the receiver cabin, and will benefit from the temperature stabilisation of the cabin.

iii. Backing Structure

The choice of materials for the backing structure is not final, but they are leaning towards a mixture of CFRP and steel, as in the IRAM 15-m interferometer antenna design. CFRP is used for the lateral members and steel for the transverse ones. In the IRAM case this was done so that the thermal expansion of the backing structure in the direction normal to the aperture plane matched that of the steel central hub. Another possibility which they are still investigating is to make the backing structure entirely out of CFRP and make the hub a box structure of CFRP sandwich panels (or possibly a CFRP cage).

In the earlier design the backing structure was supported at the rim by a CFRP cone which went back to the elevation support which had widely spaced bearings. This arrangement produced astigmatic deformations. The present design is more conventional, and has the backing structure supported on a central hub which, in turn, is supported by elevation bearings which are closer together. This appears to be more satisfactory.

The structural analysis indicates that the total absolute deviations of the structure are on the order of 200μm, and deviations from homology on the order of 3μm. Thermal analysis has not been done for the mixed CFRP/steel structure, but the CFRP structure performs well as expected.

The secondary reflector support will be a quadrupod of CFRP, mounted on the rim of the primary reflector backing structure.

The backing structure, hub, panels, and secondary reflector support will be bid as a single item. The bidders will not be restricted to the SAO design, but will be able to submit their own design which meets the specifications. It may be, however, that CFRP could be virtually mandated by a weight restriction.

iv. Secondary

The secondary mirror will be fairly small (0.45m or less) and will be nutated. Its mount will probably be based on the SMT design, and will be a separate contract from the backing structure or mount.

v. Panels

While I was at the SAO they were still unsure as to what type of panels they would use. Aluminum honeycomb panels have been ruled out because the poor thermal conduction through the panel leads to large temperature differentials and therefore distortion. The choice is between machined aluminum panels and CFRP honeycomb panels. The disadvantages of the aluminum panels are: greater weight ($32 kg.m^{-2}$ as compared with 7-$10 kg.m^{-2}$ for CFRP panels), poorer thermal stability, need to machine individual panels rather than using replication methods. The disadvantages of the CFRP panels are: cost, vulnerability of the surface in adverse weather conditions.

There is much less experience with CFRP panels than with aluminum ones. The only antennas which have used CFRP to date are the IRAM 15-m ones, and the ESO 15-m (identical design). Those panels have a 1μm layer of aluminum covered with a protective dielectric layer (Hostaflon). All the IRAM antennas have had problems with this surface. Apparently the dielectric layer is pierced by windblown dust particles and the layer starts to come away from the CFRP substrate. There are many areas where this damage has been seen, though only one or two panels have been replaced. If the holes are discovered early enough they may be patched. It now looks as though the ESO antenna is also suffering from this type of damage. (Note: The SMT panels will not have a dielectric coating, but will have a 30µm aluminum foil surface and be protected by an enclosure in bad weather conditions.)

SAO are investigating other panel surfaces and testing their weather resistance. They have one panel manufactured by Hexcel (a hexagon of dimensions ~1m) which has a 40µm layer of aluminum deposited on it. This greater thickness may be more rugged than the aluminum/Hostaflon surface. Furthermore it may be resurfaced more easily than the IRAM panels where the application of the surface is part of the panel manufacture, rather than being a separate process.

Composite Optics have not yet produced any panels for them, but they have produced CFRP sheets which have been aluminised and coated with polyethylene. There is no information on the properties of this construction yet.

SAO are also purchasing IRAM and SMT panels to test. Shortly they will test these panels by blowing dust at them at 110mph and examining them for surface damage. (I do not think that this is sufficient, since the problem may not be the immediate puncturing of the surface but subsequent de-lamination under particular weather conditions.) Another problem may be subsurface damage where the coating is not damaged but the underlying CFRP is deformed by larger particles.

vi. Enclosure

There is no firm decision as to whether or not there will be an enclosure, as this depends on how well the panels can survive the weather conditions at the site. They have kicked around a number of ideas, including a cover which would be mounted on the rim of the primary and pulled up over the secondary support legs, a screen which could be put up in front of the antenna, and a cylindrical enclosure which stands behind the antenna (and is above the azimuth bearing) and slides round the front when required.

III. Site Testing

Site testing is being carried out on Mauna Kea, which is the favoured site at present. Tests include measurement of phase stability using a specially constructed interferometer. The phase data have been compared with data from the NRAO 225GHz atmospheric tipping radiometer and significant correlation has been found. A wind speed meter will shortly be installed and will be used to measure the wind spectrum for antenna design purposes.

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