25-METER MILLIMETER WAVE TELESCOPE MEMO NO. 102

NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia

December 20, 1977

MEMORANDUM

TO: 25-m Design Group, D. Hogg, J. Baars

FROM: W-Y. Wong

SUBJECT: Notes on SAGMA 30-m Design Workshop in Bonn, Nov. 28-29, 1977

Dr. J. W. M. Baars, project manager of the SAGMA (Scientific Advisory Group for Millimeterwave Antenna) 30-m radio telescope, organized this workshop meeting, bringing together representatives from the SRC 15-m design group, the French INAG group and the NRAO 25-m design group to review, discuss and criticize their design, and to exchange detailed information concernin structural analyses, telescope performance analyses, surface plate developments and measuring techniques. Present also were members from ARGE (Krupp/MAN). Professor M. Morimoto of Japan was unable to attend, but his report on the 45-m single dish and five 10-m elements was presented by A. Greve.

In these two days, each group presented their design, special features, proposed techniques to solve their problems, and their future tasks. There were good discussions and many questions and suggestions. It is my impression that each group had made an adequate effort to substantiate their design. There are innovative approaches which might require additional effort in research and development, but there are no major engineering problems in these three designs in reaching their design goals. The purpose of this meeting was well met and all parties benefitted.

I summarize some information on these three telescopes in Table I: this table is meant more for information than for comparison. It must be emphasized that the timescales, design goals, sizes and future methods of operation are different for these three antennas, hence care must be exercised if comparisons are to be made.

I will describe in more detail the SAGMA 30-m design in the following paragraphs. I have a copy of their design report (design No. 6) for your information and reference. I can summarize my impressions after the meeting as follows:

1) With the design goal of observational wavelength λ = 1.8 mm and the diameter choosen for the telescope, their choice of an exposed and insulated telescope appears to be an economical and a correct one.

As Baars mentioned in the meeting, with all considerations taken into account, there is still no clear cut reason for such a decision. The exposed telescope requires more engineering effort in dealing with temperature and wind pointing problems whereas for the protected telescopes (SRC 15-m and NRAO 25-m), these problems are not the main concerns for the design of the elevation structure. As one can see in Table I, the total amounts of steel (elevation structure and the protective structure put together) of these three designs are not vastly different from each other. The extra effort required from the SAGMA 30-m design group will be offset by the money saved in not acquiring an expensive protective dome.

2) The lack of in-house engineering effort by the SAGMA 30-m group, in spite of excellent support from B. Hooghoudt and ARGE, made the feasibility studies more costly and less flexible compared with the SRC and NRAO groups. However, this arrangement enables their prospective construction firms to proceed smoothly and with a high degree of confidence into the detailed design and construction phase. For the other groups, especially that of the NRAO, time must be allowed for the lengthy process of having an outside firm understand and eventually undertake such a task. Building an 80-ton structure while requiring the rms deviation of the surface points from the best fit paraboloid to be less than .016 mm is not a trivial task with a given cost, and will require a great deal of effort. It took us one year to convince one firm that they could indeed produce surface plates with an rms surface error of .040 mm at a "reasonable" price.

SAGMA 30-m Telescope

General Description

The basic design concept of this telescope is rather similar to the 25-m Stockert telescope, due to its compact construction, its large amount of available space in the supporting tower, and its stationary working area behind the vertex cabin (Fig. 1). According to their engineers, this design made it specially suitable for an open air, exposed telescope. The entire telescope, except for the surface plates, is covered with an insulating envelope. There is an air circulating system within this envelope, as well as heating elements to get rid of ice.

Reflector Structure

This is composed of four main parts: a heavy elevation yoke, a circular plate, 40 radial ribs and its quadrupod system. The circular plate is supported by the yoke at its center, with structural tubes trussed against the yoke at the rim in such a way that the deformation of the plate is homologous. The design of the radial ribs, which are supported by the plate, is hence simplified, making the task of reaching a homologous telescope relatively easy. The structural analyses are done with beam elements for the radial ribs, plate elements (over 1,000 were used) for the circular plate, and the heavy yoke structure. Presently these analyses are being done in steps, and eventually all these components were coupled together in a single large model to verify the results.

The reflector structure is driven in elevation by two sets of drives on each of the two elevation bull gears. The pinions on each set are preloaded by a bias torque and both sets are electronically synchronized through encoders, one for each axle. The distance between the elevation bearings is small compared with the diameter of the reflector ($\simeq$ 1/4 D), hence the stiff yoke structure replaces the need for an elevation axis. This arrangement provides an unobstructed working space behind the vertex cabin for the receivers in the Cassegrain system. The yoke structure is stiff so that vibration in a torsional mode about the elevation axis will not occur when the telescope is under automatic control, and the reflector will not deform due to the force and turning moment produced by a 14 m/s wind from any direction. The design will be finalized after more data are obtained from a wind tunnel study next year (cost $\simeq$ 50 - 60 K DM).

Azimuth Structure

The azimuth motion is driven by two drives, with one set against the other to minimize backlash during tracking. The conical steel and concrete tower supports a large (5-m in diameter) composite bearing, and, in turn, the bearing supports a steel azimuth cabin. Accessibility to the vertex and the available space make this arrangement attractive. The bearing is stiff in its radial and axial directions to sustain the weight of the reflector and any wind force. Deflection due to wind forces from the azimuth cabin, bearing, and the tower are so small that they will not affect the pointing of this instrument.

Soil Condition

The ground in Pico Veleta is composed of a large layer of loose gravel on the top of fractured rock (mica-chisto). Recent sub-surface investigation showed some fractures of 20 to 30 centimeter width. The present proposal calls for grouting to fill up these fractures and for excavation to remove loose gravel. Again, consideration will be given to making the foundation stiff against wind forces.

Insulation Envelope

The open air, exposed design, together with a construction of heavy (yoke) and thin (radial trusses) structures, make it necessary to have the entire structure insulated. The insulation envelope serves two purposes; to lengthen the thermal time constant of the structure and to furnish some temperature control within itself to reduce temperature gradients. The insulation panels are made of 4 to 6 cm thickness of foam protected by a thin sheet metal, with heating elements inserted inbetween. These insulation panels are attached to the reflector structure, forming an envelope: figure 2 illustrates an antenna with similar kind of insulation. Studies of the heat transfer problems of this insulated structure were done with in-house effort, concluding that in an average sense temperature differences at any part of the reflector structure can be kept within 1°C with the aid of air circulation.

The azimuth tower is also insulated by foam.

Surface Plates

The surface plates are the only exposed, hence unprotected, element of the telescope. It is suggested that the plates should be low in heat capacity and high in heat conductivity. Considering the various types of materials, costs, and future setting techniques, it has been concluded that a honeycomb aluminum sandwich construction with nine adjustment screws is the most acceptable choice. The latest plate was produced by MBB (Messerschmitt-Bölkow-Blohm GmbH, München), and its manufacturing tolerance is estimated to be .050 mm rms or less.

The surface area of each plate is about 1 m^2 on average. A steel frame module supports 4 plates and the plates are accurately set in the frame module. The corners of the frame module are equipped with adjustable screws and are to be adjusted to the best fitted paraboloid on the telescope structure. This setup will reduce the adjustment effort on the telescope by a factor of 4.

Surface Measurement

Three methods have been taken into consideration but no decision has been made. These three methods are 1) the stepping method developed at NRAO. 2) a laser interferometer and 3) distance measurement using a modulated laser. Some developments of the holographic or the Scott & Ryle radio-frequency method may also be tried, particularly as a way of monitoring the telescope stability over long periods of time.

UK 15-m Telescope

1) Barry Shenton is retiring after Christmas 1977, and Jim Hall is replacing him as Project Manager. Bryan Colyer of Rutherford Lab is responsible for the mechanical and structural design of the telescope. Tim Smithers of Cambridge Engineering Lab is developing an optimization program on geometry of the structure. Richard Hill is the Project Scientist.

2) The project will not be approved by the Department of Education and Science before the site problem is solved. They have yet to make a decision on the site.

3) The prototype surface plate has proven that their proposed manufacturing method of aluminum honeycomb sandwich construction is indeed feasible. They will specially design and assemble a dedicated machine for this purpose. Presently they don't have a .040 mm rms surface plate of the full size required.

4) The reflector structure is similar to the MPI 100-m in concept. The homology solution is achieved by trial and success.

5) The reflector will be driven in elevation by a direct drive, and in azimuth by 4 motors with gear reduction.

6) They have a prototype laser interferometer for surface measuring built and it is in good working condition.

7) They will build a small section of the reflector to verify their structural calculations.

TABLE I

MAJOR DESIGN PARAMETERS FOR THE UK, USA AND GERMAN RADIO TELESCOPE

ITEM	UK/SRC	US/NRAO	German/SAGMA
Reflector Diameter	15-m	25-m	30-m
Operational Wavelength	0.8 mm	1.2 mm	1.8 mm
Shorter wavelength at reduced efficiency	0.4 mm	0.8 mm	1.2 mm
Weight of the elevation structure	16,500 Kg	74,800 Kg	340,000 Kg
Protective structure	Astro-dome	Astro-dome	Exposed
Weight of protective structure	360,000 Kg	370,000 Kg	--
Cost of entire project	6.5 M$	12.5 M$	7.6 M$
Site and its latitude	?	Mauna Kea (20°)	Pico Veleta (37°)

Surface Plates	Al. Honeycomb	Machine Al.	Al. Honeycomb
Weight	12 Kg/m^2	20 Kg/m^2	50 Kg/m^2 *
Unit Cost	$3000/m^2	$3000/m^2	$1200/m^2
Accuracy	20 μm	40 μm	50 μm
Surface Area	~190 m^2	540 m^2	~780 m^2
Cost	.56 M$	1.6 M$	.94 M$
% of Total Cost	9%	13%	13%

* The weight of steel supporting frame is included.

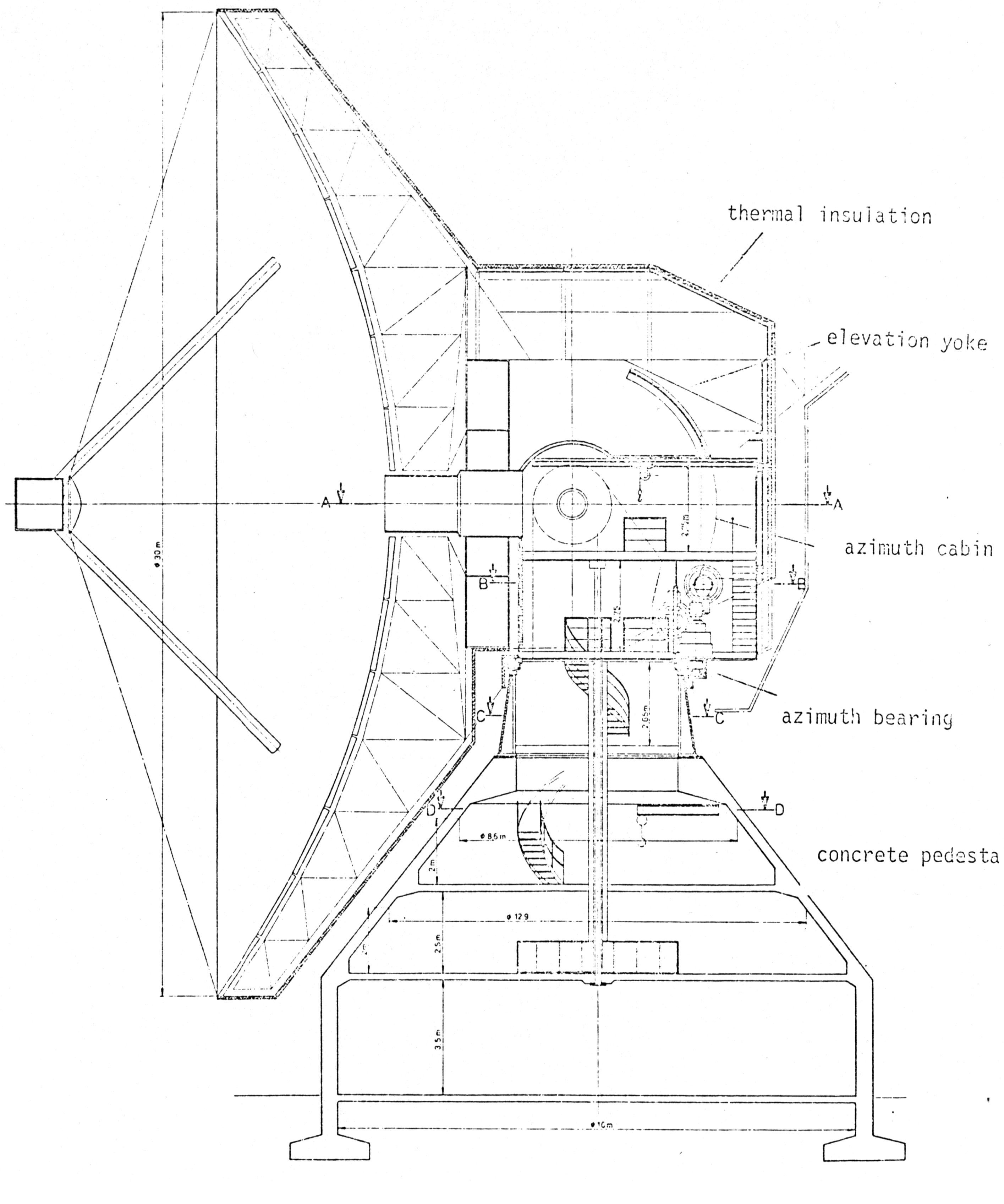

Fig 1 Cross-section of the 30-m telescope

FIG. 2. Communication Antenna No. 2 in Raisting, Germany, has an insulation envelope similar to that proposed for the 30-m radio telescope.