UNITED KINGDOM/NETHERLANDS MILLIMETREWAVE TELESCOPE ANTENNA

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The U.K. Science and Engineering Research Council, joined by the Netherlands Organisation for Research in Pure Science, are constructing a 15 metre diameter Cassegrain reflector antenna capable of operating at wavelengths as short as 0.4 mm (750 GHz). This paper describes the antenna and the special features which are necessary to enable such a large reflector to operate efficiently at these very short wavelengths.

The millimetre telescope is due to be constructed on Mauna Kea in Hawaii at an altitude of 4100 m and commissioned in 1986. A symmetric Cassegrain dual reflector was chosen for the telescope because this met all the radioastronomical requirements and the high precision could be achieved with very careful use of existing design technology. The specified surface accuracy is 50 μm. This includes manufacturing tolerances, measurement and setting, thermal and gravitational distortions and ageing. Success in achieving these specifications means that it is realistic to set a goal of 35 μm surface error. The boresight error for tracking astronomical sources will then be 1 arc seconds, and the antenna will have a gain of about 95 dB with a beamwidth (FWHM) of 6 arc seconds at 0.4 mm wavelength. The use of a symmetric reflector has enabled a chopping subreflector to be incorporated which switches the beam on and off a source to effect atmospheric emission cancellation. The antenna will be housed in a rotating carousel with a membrane covered viewing window so that protection from the weather is provided, Fig. 2.

PRIMARY MIRROR

The primary mirror is homologous in design so that the shape remains a paraboloid as it is tilted under gravity. This is done by a symmetric backing structure made from tubular members upon which are mounted panels which form the primary surface. The panels are relatively small (approximately 1 m square) so that their self-weight deflections are of secondary importance. There are 276 panels arranged in 7 rings. Each panel is constructed by stretching a 0.5 mm aluminium skin over a numerically machined steel former and glueing a layer of crushed aluminium honeycomb on to the back. A flat aluminium-honeycomb-aluminium layer is then glued on to provide the required stiffness.

Panels are being produced routinely by this method and have an rms surface accuracy of better than 15 μm. The panels are attached to the backing structure at three points by remotely controlled jacking screws. These have a resolution of 3 μm and will be used to set up the shape of the paraboloid. In the initial setting up an alignment laser and optical interferometer will be used to determine the absolute position of the panels. Later on it is hoped to use microwave holography to monitor the shape of the primary mirror.

SECONDARY MIRROR

The secondary mirror is hyperboloidal with a focal separation of 9.136 m and a diameter of 750 mm. The focal length of the primary is 5.4 m so the secondary focus is behind the primary vertex. A third, plane mirror behind the vertex and on-axis will be used to direct the beam to one of four receiver positions. The magnification of the secondary is 33.3 and the effective focal length of the primary is then 180 m. The resultant focal ratio of 12 is almost ideal for coupling to quasi-optical diplexers and gives a good field of view for imaging. The diameter of the secondary was chosen to be a compromise between low inertia so that rapid tilting is possible and ensureing that diffraction losses are kept within acceptable limits. The hole in the primary vertex is larger than the diameter of the secondary so aperture blocking is not a design factor.

The high pointing accuracy and rapid tilting required for beam switching has a considerable influence on the design of the subreflector and its support structure. Servo controlled movements allow the subreflector to be aligned so as to compensate for the effects of gravity. Electromagnetic vibrators produce the necessary rocking motion to the subreflector in order to displace the main beam by up to 5 arc minutes at a frequency of 2.4 Hz. The subreflector will be supported by an eight leg structure. This was chosen instead of the more conventional four leg structure in order to achieve torsional stiffness. The eight legs lead to increased blockage but this is partly offset by reduced leg diameter.

PREDICTED PERFORMANCE

Extensive theoretical predictions have been carried out to assess the performance of the antenna. The quasi-optical feed system means that it is reasonable to assume a Gaussian aperture distribution with an optimum gain taper of -10 dB. A 12% loss in gain arises from aperture blockage. This is made up of the subreflector supports, the central hole in the primary and gaps between the panels. Spillover past the reflectors causes a further 10% loss in gain and the non-uniform aperture illumination about 7% loss in gain. There are also rather smaller frequency dependent losses due to subreflector diffraction and ohmic losses in both primary and secondary.

Efficiency reduction will also result from the phase errors due to panel irregularities, misalignments of the panels, feed and reflectors. The total predicted efficiency is shown in Figure 3 for (a) the membrane removed and 35 μm surface error; (b) the membrane present and 50 μm surface error.

Fig. 4 shows the predicted radiation pattern around the main lobe due to gravitational distortions and with the antenna pointing at the horizon (worst case). This is the main cause of pattern deformation. Other small scale distortions scatter power over a wide range of angles. The patterns were calculated by taking the panel positions as predicted by structural analysis and then determining the optimum position of the subreflector to give maximum gain. This removes the largest phase error and a satisfactory radiation pattern is predicted even at 0.4 mm wavelength. The loss in sensitibity at the peak of the main beam corresponds to an effective rms surface error of 11 μm for horizon pointing.

The telescope views the sky through a woven PTFE cloth membrane which is transparent at the frequencies of operation. The membrane causes gain loss of about 5% at 0.44 mm wavelength due to dielectric loss, reflections and phase distortion because of curvature, non-uniformity and seams. The cloth is made up of woven threads so that the membrane has different transmissions for two polarisations. This is estimated to lead to 1.5% instrumental polarisation at wavelengths less than a millimetre. The noise temperature increases due to both dissipation and reflection. This increase is estimated to be about 16 K at 0.4 mm and 7 K at 1 mm.

ACKNOWLEDGEMENTS

The 15 m telescope is being built through the efforts of a large team from a number of institutions in the U.K. and the Netherlands. It is a pleasure to thank all our colleagues on this team for their contributions to the project.

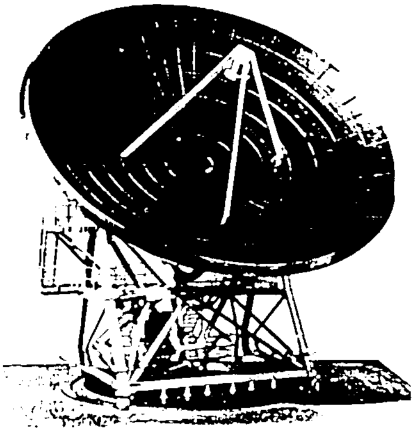

Fig. 1. Model of UK/NL Millimetrewave Telescope Antenna

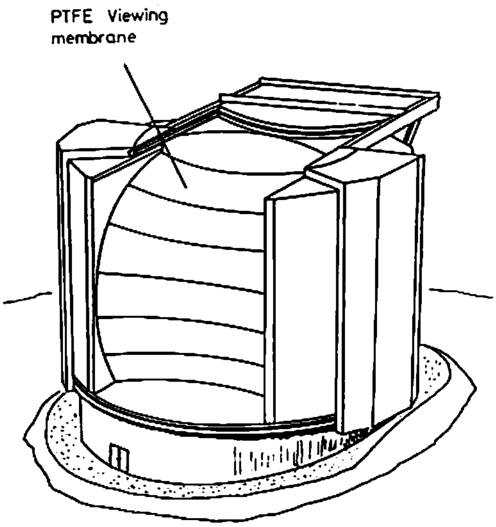

Fig. 2. Carousel

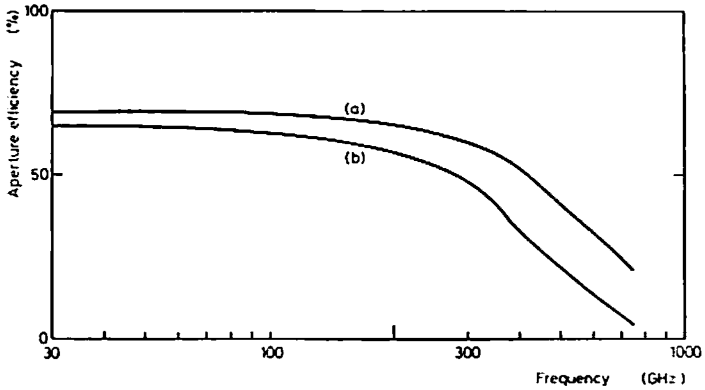

Fig. 3. Predicted Efficiency

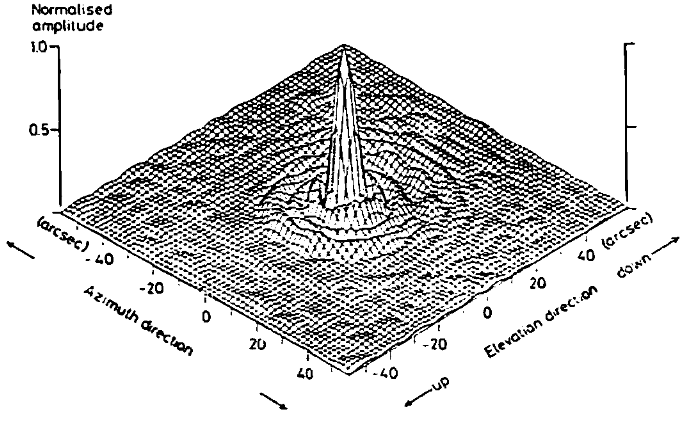

Fig. 4. Radiation pattern with antenna pointing at horizon