NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia

January 7, 1976

MEMORANDUM #37

To: The 25-meter Telescope Design Committee

From: J. W. Findlay

Subj: Radome Materials for Millimeter Waves and Other Matters

During a recent visit to England I have looked further into the measurement of loss of various possible radome materials. I also talked with R. E. Hills and others in Cambridge about the design work on their 15-meter telescope.

Radome Material Tests

I visited the National Physical Laboratory at Teddington to see the methods by which loss measurements are made. The instrument used is a Michelson interferometer used as a Fourier Transform Spectroscope. (See the book by G. W. Chantry -- Submillimeter Spectroscopy, 1971 or the recent article in Science by Bates, vol. 191, pp. 31-37, 9 January 1976.) Essentially this technique measures the absorption spectrum of the sample of material. The illumination source is a mercury vapor lamp with a quartz envelope and the detector is a helium cooled Rollin detector. The sensitivity of the system falls at the longer wavelengths. Measurements have been made as low in frequency as 90 GHz but the method is best from about 200 GHz upward in frequency.

To make a measurement of fractional transmission of a specimen of material requires only that the emission spectrum of the source of infrared in the interferometer be measured with and without the material specimen in one of the two interferometer paths. Thus the fractional transmission, found as a function of wave-number, includes losses due to true absorption in the material and also due to reflection from the sample.

The accuracy of the method is perhaps as high as ± 2% in determining transmission at about 300 GHz.

$\lambda = (.28)\sqrt{2}\ 4$? λ = Tramisson Wave length (mm)

$\frac{\lambda}{4} = T\sqrt{\text{Dielectric}}$ - T = thickness (mm)

The NPL group is in the Electrical Science Division (Superintendent Mr. A. E. Bailey) and the work is directed by Dr. G. W. Chantry. Measurements have been made of many materials, including some from the United States. One material with good transmission which we have not thought of is sailcloth--some specimens have transmission as high as 0.96 at 300 GHz and have quite considerable strength.

The NPL group will continue to measure the losses in materials which might be used for the UK telescope. It does not seem necessary at present for us to ask them to measure any new materials, since they will, almost certainly, cover all reasonable possibilities.

It may be worth noting that the technique and practice of F. T. Spectroscopy are well established and tested. The equipment used at NPL is their own development, but there are several instruments commercially available of a similar design. The results are certainly reliable.

Possible Work at NRAO

There seems to be no reason why we should duplicate any of the measurements made by NPL. If there do happen to be materials which we wish to have measured, they are sure to be of sufficient interest to the UK group that they would include them in their measurement plans.

P. Napier thinks we should be wise to make a few spot checks of materials of great interest to us, using standard millimeter-wave radiometric techniques. This we could easily do without setting up a specific experiment, merely by using existing mm-wave radiometers as they are built in Charlottesville or when they are being tested at Kitt Peak. Such spot checks would be an insurance that no unforeseen errors have occurred.

In my opinion we should go ahead quite rapidly with outdoor exposure of likely radome materials. I think we should use Mauna Kea as a site for such tests. Whether we use it or not as an observatory site, it sounds as if it would be one of the best for testing--its uv flux must be quite high and it has wind, and some wind-blown dust.

We should expose materials and have their transmission loss measured before exposure and after an interval of a year. We should examine and test the materials for mechanical changes after exposure. The object of these tests would be to detect the unsuitable materials and to cover unknown effects. Although I made no formal agreements in the UK, I believe they would be interested in having some materials measured and exposed in such a program. This could be a useful contribution on our part, and I will discuss it further with the UK group. I also need to find out whether ESSCO already have done tests of this kind.

One property of radome materials which is not measured directly in the NPL tests is the way in which they scatter energy out of the incident wave. Of course, any such energy scattered from the wave-front will appear as a transmission loss in the NPL measurements--so that low-loss implies small scattered energy. Nevertheless, the quasi-regularity of the structure of some of the materials might lead to an unpleasant angular distribution of even a small amount of scattered energy. The angular spectrum of the scattered waves is related to the Fourier transform of the structural regularity. Thus, for example, Griffolyn is a thin film with an embedded net which has a roughly square mesh of about 10 mm in size. It would thus behave like two crossed phase gratings; maximum scattered power would be about 7° from the main beam (for $\lambda = 1.2$ mm) for each grating.

For most other materials which have a quasi-regular structure, the structure scale size is a millimeter or less. Scattering from such structure at 1.2 mm is not likely to be troublesome.

Nevertheless, the question as to whether the scattering properties of the materials should be studied is worth considering. The effect of scattering from a quasi-regular structure is to add an unwanted side-lobe to the antenna pattern. Even if the mesh is randomized in orientation on the radome panels this will still be true.

The scattering properties could be measured by a microwave system. Probably the easiest measurement would be to observe the pattern of a plane-wave antenna (a horn-paraboloid for example) with and without a sheet of material over the aperture. An antenna about 20 cm in aperture at 150 GHz has a HPBW of about 50 arc minutes and a far-field distance of 10 meters. Such an experiment could be done on the Green Bank antenna range.

Other Notes on the UK Telescope

I learnt in talking to Richard Hills that the UK telescope plans are going steadily forward. Two firms (Marconi and Hawker-Siddeley) are working in parallel on design studies for the telescope and its enclosure. Hawker-Siddeley have studied our surface measuring technique, and I hope sometime to get a copy of their comments. They have also worked out a direct method using laser interferometry--certainly a method which can give the required accuracy.

I did not trouble to get clear the whole picture of how the UK telescope is being managed. B. Shenton is the project manager and R. E. Hills I would describe as the project scientist. There is a committee overseeing the whole thing, and Tony Hewish has just become chairman of this. But I may not have got all the details right. The NPL group, as I understand it, are working on the general task of radome material suitability for the telescope project.

Atmospheric Measurements at Mauna Kea

I learnt at the Appleton Laboratory that a small group of scientists led by Dr. H. A. Gebbie will be carrying out experiments this January on Mauna Kea. They will, I believe, be measuring atmospheric absorption and radiation in the submillimeter range. The results may be of interest to us.

JWF/pj