SUNSCREEN FOR THE 11-METER TELESCOPE

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I. INTRODUCTION

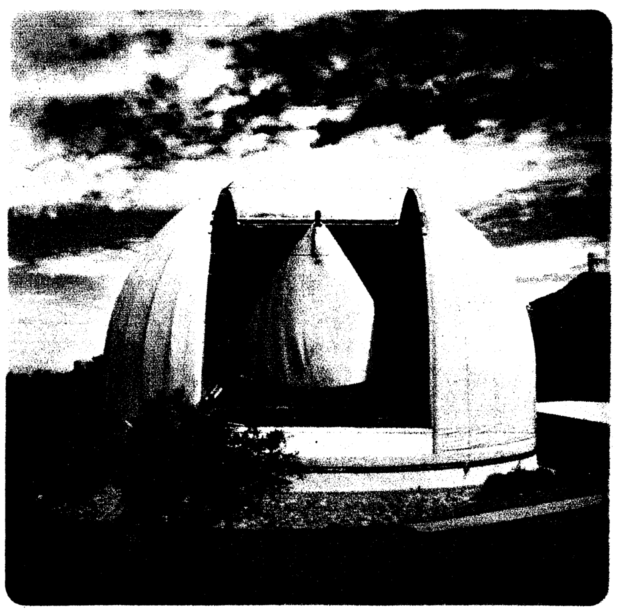
The performance of the NRAO 11-meter telescope on Kitt Peak is degraded when direct sunlight falls on the primary mirror, on the backup structure, or on the feed support legs. The telescope focal length generally increases, the gain decreases, the half-power beamwidths increase, the relative sidelobe levels increase, and the pointing can change up to a minute of arc. All these effects impair the efficiency and accuracy of astronomical observations, especially at the short millimeter wavelengths where the degradations are more serious. The fabric-covered astrodome surrounding the telescope can be used to shade the telescope from direct sunlight since the fabric is translucent in the visible and near infrared. However, observations of sources within about 45^{o} of the Sun's direction generally require that the astrodome door be closed and that the source be viewed through the semi-transparent fabric. Of course the metal space frame which supports the fabric also blocks some of the signal and reduces the telescope gain by about 15%. At 3 mm wavelength the combined effect of the astrodome frame and fabric is to reduce the efficiency by a factor of about 0.57, which is a very significant decrease in sensitivity. In addition, reflections from the dome walls may cause standing waves which degrade the instrumental baseline for spectroscopic observations.

Several schemes have been suggested in the last two years to shield the telescope from sunlight without seriously degrading the radio frequency performance. Clearly a low-pass filter is needed which ideally will block all visible and infrared solar radiation while completely transmitting microwave energy. The first suggestions involved stretching a thin fabric membrane over the astrodome slit, supported only around the perimeter. However, calculations by Tony Hamed and others showed that wind forces were quite severe and that because of the flexure in the astrodome itself it would be impossible to secure a thin membrane of the required size (at least 12 m x 12 m) without significant additional structural blockage. Consequently, a different approach was tried: enclosing the telescope itself in a plastic bag. Tests on radome fabrics for the 25-Meter Telescope project showed that one material called Griffolyn T-55 would be an acceptable low-pass filter of sufficient mechanical strength, and in 1977 Tony Hamed and I designed the first "tepee".

II. DESCRIPTION

The sunscreen design evolved into the familiar Indian "tepee" since that is the basic shape of the dish and feed support structure. Figure 1 is a picture of the sunscreen installed on the 11-m telescope. The fabric is sewn into a large cone which is attached to the perimeter of the reflector and to the apex of the feed support legs.

FIGURE 1

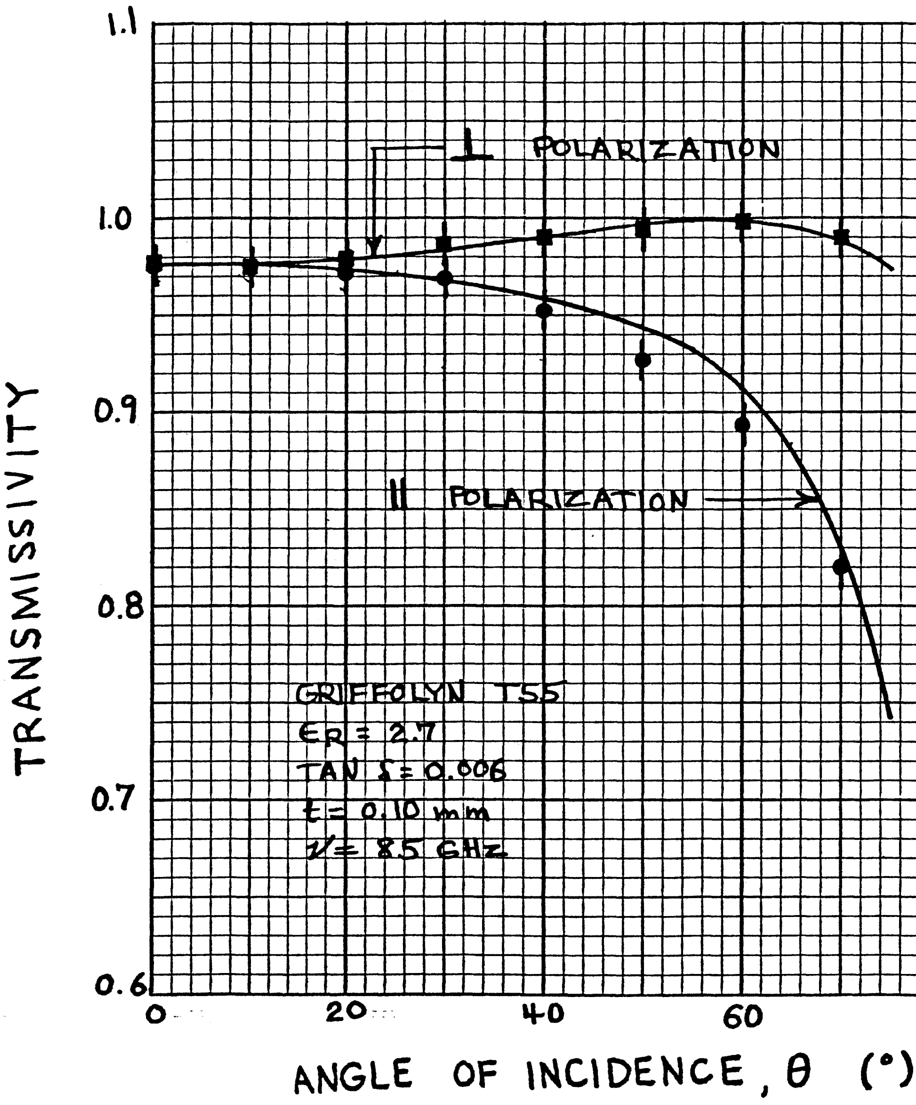


Additional support is provided internally by air pressure. A large blower and air conditioner were already mounted on the telescope service platforms to cool prime focus receiver boxes. Additional flexible hoses were added to simply divert the cooled air through the reflector and inside the tepee. A fairly tight seal was made around the rim of the dish so most of the air would eventually circulate toward the apex to spoil vertical temperature gradients inside the tepee. The small differential air pressure is sufficient to inflate the tent and keep it from flapping in light to moderate breezes. In winds over 15 mph caution must be exercised in observing since in some directions the cross sectional area and thus the wind torque is large. Consequently the torque motor currents should be closely monitored to prevent overheating or telescope runaways. Zippered access panels are located near the edge of the reflector and on both sides of the primary focus. In addition, a long zipper around the base of the cone and up the lower feed leg allows Cassegrain receiver boxes to be installed without removing the tepee.

III. RF PERFORMANCE

Griffolyn T55 is a sandwich of black and white polyethylene sheets with a coarse nylon netting in the center. The total thickness is 0.10 mm. Figure 2 is a plot of measured power transmissivity versus angle of incidence at 85 GHz. The solid curves are a homogeneous dielectric model which was fit to the

FIGURE 2


⊥ POLARIZATION
∥ POLARIZATION
GRIFFOLYN TS5
$\epsilon_R = 2.7$
TAN δ = 0.006
t = 0.10 mm
ν = 85 GHz
TRANSMISSIVITY
1.1
1.0
0.9
0.8
0.7
0.6
0
20
40
60
80
ANGLE OF INCIDENCE, θ (°)

data by least squares. The electrical parameters derived from this fit are a relative dielectric constant of 2.7 and a loss tangent of 0.006. As an additional check I computed the transmissivity at normal incidence as a function of frequency, and as shown in Figure 3, the agreement with measurements is quite good. Of course, the angle of incidence on the telescope is not normal, but rather 61^{o}, and Figure 4 shows the calculated average loss for both polarizations as a function of frequency. This curve then represents the signal loss when observing with the sunscreen on the telescope. Since the fabric is quite thin the first quarter-wave resonance occurs at extremely high frequency (> 400 GHz). At 3 mm wavelength the signal loss is only about 6 % and thus observing through the sunscreen is almost three times faster than observing through the side of the astrodome. The increase in system noise temperature is about 15 K, and the effects on spectral line calibration and on spectroscopic baselines are negligibly small. Similarly, pointing, focus, and beam shape are not noticeably affected by the sunscreen.

The transmission of Griffolyn T-55 to solar radiation was measured to be 13 ± 5%, and tests on the telescope also indicate some greenhouse heating of the air inside the tepee. Consequently the air conditioner should be used in the daytime to keep the maximum temperature inside at a level the Cassegrain box temperature controller can handle. Some caution should also be used when observing partly in sunshine since the feed legs can be

FIGURE 3

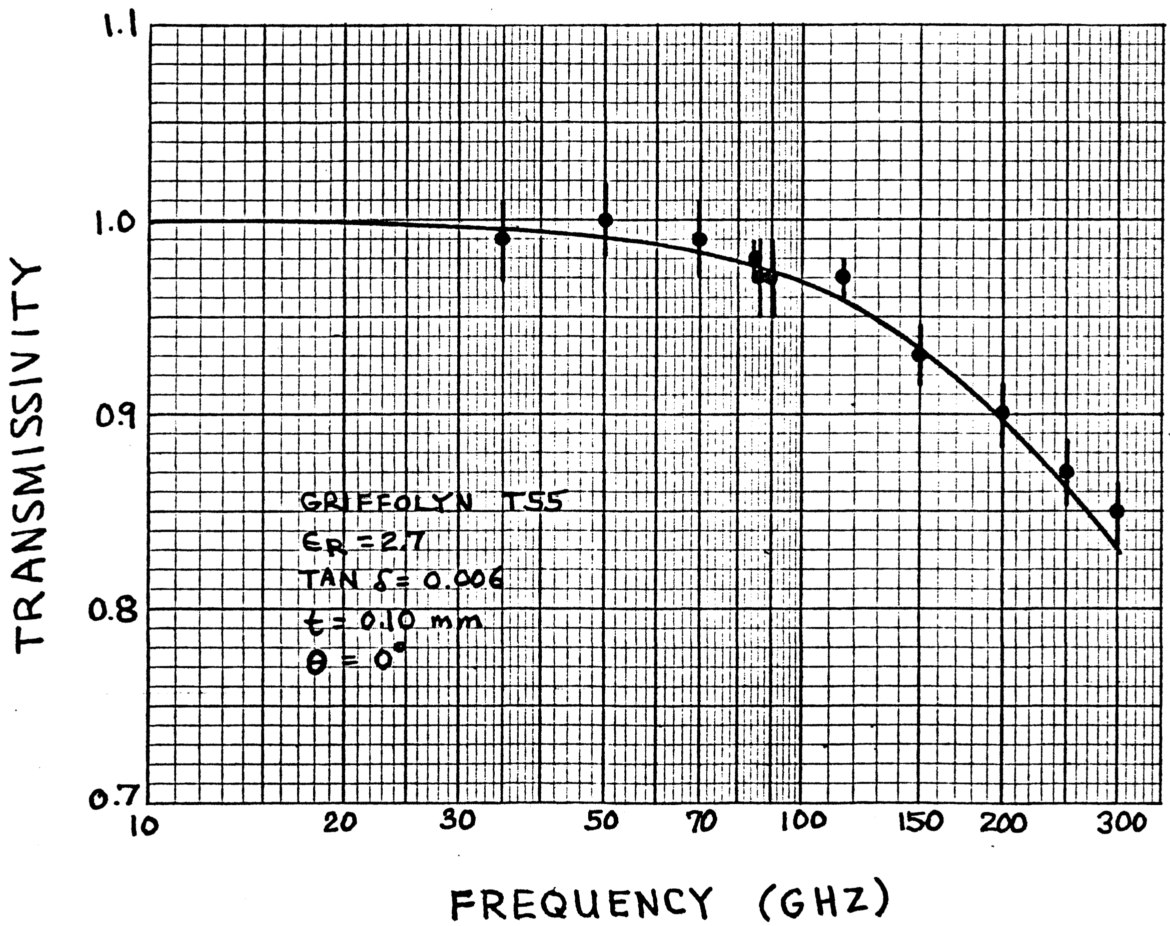
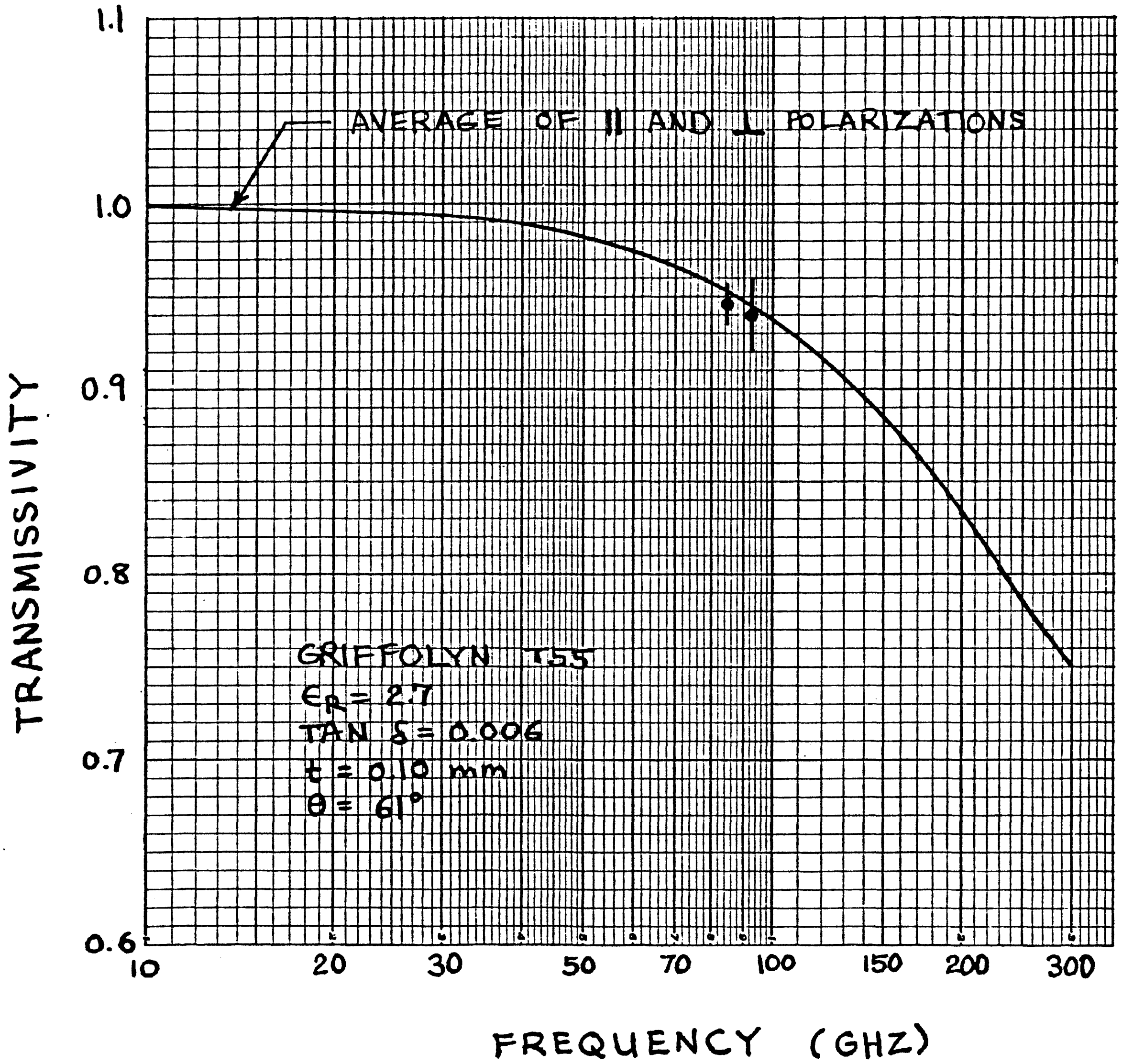

1.1
1.0
0.9
0.8
0.7
TRANSMISSIVITY
GRIFFOLYN T55
ϵ_R = 2.7
TAN δ = 0.006
t = 0.10 mm
θ = 0°
10
20
30
50
70
100
150
200
300
FREQUENCY (GHZ)

FIGURE 4


AVERAGE OF || AND ⊥ POLARIZATIONS
GRIFFOLYN T55
ЄR = 2.7
TAN δ = 0.006
t = 0.10 mm
θ = 61°
TRANSMISSIVITY
1.1
1.0
0.9
0.8
0.7
0.6
10
20
30
50
70
100
150
200
300
FREQUENCY (GHZ)

slightly heated by solar radiation through the fabric and appreciable pointing errors (∿ 30 arc sec) can result. The sunscreen can be installed by 3 people in about 1 1/2 hours and removed in about 1 hour. The total cost for design, development, fabrication of two units, and testing was about $6 K.