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Subject: Some tests of radome panel losses

1] Panel model used in efficiency calculations

The model which has been traditionally assumed for radome panels is a uniform dielectric slab 24 mils thick with dielectric constant of 2.8 and loss tangent of 0.011. This model appears to be somewhat optimistic in predicting the loss at 43 GHz.

2] Physical appearance of panels

The panels are made of 2 layers of woven dacron cloth epoxied between outer layers of tedlar. The tedlar film is 1.5 mils thick and the overall thickness of a panel is about 30 mils between peaks of the surface. Surface roughness is about 2 mils peak-top-peak. At present, little information is available about the microwave properties of these components.

3] Water absorption

Some small pieces of a panel with exposed edges were soaked in water. Measurements of the low frequency dielectric constant placing the panel between the plates of a capacitor showed that the capacitance returned to its "dry" value within about 30 minutes. Tests were also made of the attenuation at 43 GHz as the panel dried. No significant attenuation increase over the dry value was measured after the panel was dried with a paper towel. While some concern remains that water could get "wicked" into the dacron tests for this potential problem gave negative results. Theoretical calculations estimate that if 1% of water (by volume) were absorbed it would add about 0.3 dB loss at 43 GHz. (The Debye formula for the complex refractive index was used and at 5°C produces a maximum attenuation at about 43 GHz.)

4] Brewster angle check

One check on the scattering of microwave radiation from irregularities and loss can be made by checking for perfect transmission of a TM wave (E-vector in the plane of incidence) at the Brewster angle θ given by $tan^{-1}\epsilon^{1/2}$. The Brewster angle was measured at 43 GHz and found to be 60$\pm$5 degrees with a minimum loss of 0.15$\pm$0.05 dB. The accuracy of the angle measurement doesn't provide a useful check on the refractive index but the presence of some loss shows that the panels have some dissipation or scattering loss.

5] Transmission loss measurements and new model

An approximate gaussian beam was set up by transmitting through a long horn whose 5"x3"aperture was blocked down to about 1"x1"with a microwave absorber. A similar horn a few inches away was used to receive the beam and convey the signal to a wavemeter and power detector. Some residual multiple reflections were averaged out by sweeping the signal over about 1 GHz. Figure 1 shows the loss measurements which were made at an angle of incidence of about 20 degrees. While the measurements above 70 GHz fall close to the traditional model of a uniform dielectric, the measurements at 22, 42, 46, and 50 GHz have much larger attenuation values than given by a uniform dielectric. In order to get a reasonable fit to the data I was forced to explore composite models with variations in thickness and/or dielectric. One model which fits quite well has alternating sections with $\epsilon=3.6, \tau=23$ mils; and $\epsilon=2.7, \tau=33$ mils. While this model may not be unique, it bears some resemblance to the variations which one might expect as a result of the weave.

6] Microwave temperature of panel and Haystack aperture efficiency

The larger than expected loss of panels at 43 GHz have resulted in an overestimate of the antenna surface roughness loss from 43 GHz radiometry. Also, given that some of the panel loss is either dissipative or the result of wide angle scattering, we should expect the radome loss to be "warmer" than expected. At low frequencies, the antenna temperature (excluding atmospheric contribution) is about 40°K (Sandy Weinreb measured 35°K with a horn in the radome - but the lowest antenna temperatures observed are around 40°K) and if the panel loss were all dissipative the 1.2 dB loss at 43 GHz would add 73°K for a total of 112°K. The irregularities in the panel structure will also modulate the backscatter phases but even if the reflection changes location from the front surface to the back surface, the "equivalent rms" of the panels could only be about 12 mils. A test of the panel reflection at 43 GHz shows that most of the 1.2 dB loss is accounted for in a specular reflection at -8 ± 1 dB. The best estimate of scattering or dissipative loss at 43 GHz is 0.15 dB or about 10°K from the residual loss at the Brewster angle. However not all the specular reflection from the panels is reflected back into cold sky and some (from the outer regions of the dish where the angle of incidence is high) is reflected from the ground. A new calculation using the method of Meeks and Ruze but accounting for the reflection changes with angle of incidence gives an added 30°K from reflections. To summarize at 43 GHz:

Radome space frame and spillover	40°K
Radome panel dissipation	10°K
Radome panel reflections	30°K
Total antenna temperature (excluding atmos.)	**80°K**

Acknowledgement

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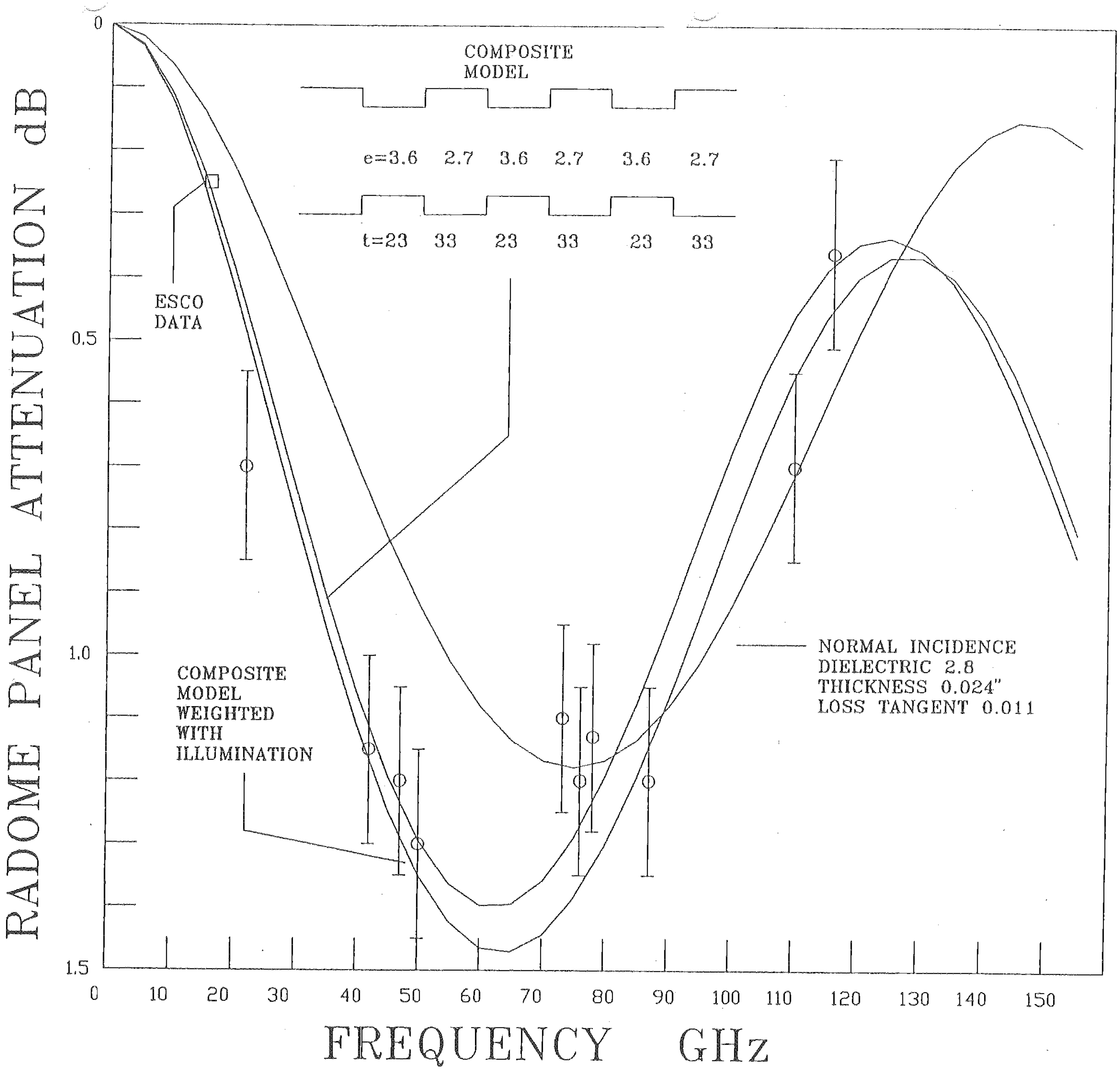

FIGURE 1 Panel attenuation vs model