GBT MEMO 74

National Radio Astronomy Observatory
Tucson, Arizona

February 28, 1992

MEMORANDUM

To: R. Hall, GBT Memo Series

From: James Lamb

Subject: Paint Performance at Millimeter Wavelengths

I. Introduction

This note presents the results of measurements of the loss at millimeter wavelengths of the paint to be used for the GBT panels. One set of measurements was performed under contract by the National Physical Laboratory, England. The other was done at NRAO. From the measurements it may be concluded that the dissipative loss in the paint is negligible up to 100 GHz, and probably to 250 GHz. There appears to be some scattering loss (of order 5%), although the effect was difficult to measure because of the lack of flatness of the samples.

II. Loss at 90 GHz

An SIS radiometer was set up and tuned to 90 GHz. An aluminum mirror was placed at 45° in front of the receiver to deflect the beam horizontally through 90° (Fig. 1). A liquid nitrogen cold load was set in the beam as close to the mirror as

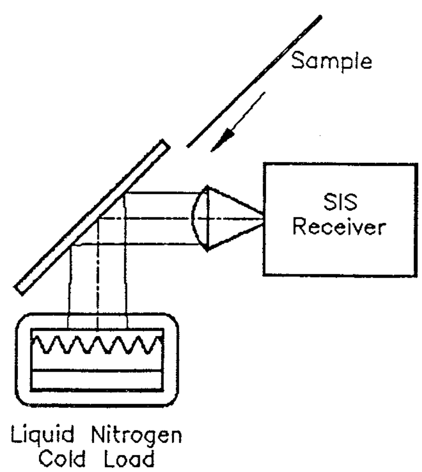


Figure 1. Setup used for measuring dissipative loss in samples at 90 GHz.

possible. When the samples were placed on the front of the mirror, the output power was constant to within 0.01 dB. Knowing that the receiver noise temperature is about

50K, it may be deduced that the loss in the dielectric is less than 0.3% relative to the aluminum mirror.

III. Scattering at 90 GHz

To measure the scattering, the cold load was moved to about 2 m from the mirror (Fig. 2). A piece of absorber with a 6 cm diameter hole was fixed in front of

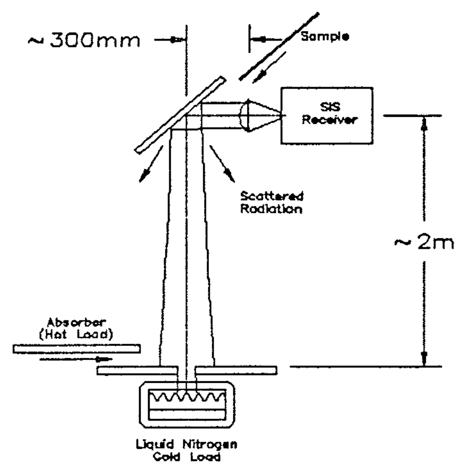


Figure 2. Setup used for estimating scattering loss at 90 GHz.

the cold load so that only the central portion of the beam was intercepted. A reading of the total power was taken, and then another with the hole covered by a piece of absorber at ambient temperature. Another set of readings was taken with each of the sample plates in front of the aluminum mirror. The ratio of the hot-cold differences then gives the loss. Since this is measured for the center of the beam and it is known from the previous section that there are no dissipative losses, it must be a direct measure of the scattering loss.

Since the plates were not perfectly flat, they were clamped to the aluminum mirror to reduce the buckling as much as possible. This was not entirely successful since there was considerable scatter in separate measurements of a single sample. In addition, some measurements showed gain indicating that the beam was being refocused. Some rough estimates are in reasonable agreement with the observed bending of the plates. To minimize these effects, several measurements were made on each plate using both sides. The overall result indicated an average loss of about 5%, but with a standard deviation of about 5%. No systematic dependence on paint thickness was found. We conclude that there is probably some scattering due to the surface roughness of the paint, but it is only at the level of about 5%.

IV. Loss Measurement at 130-360 GHz

The National Physical Laboratory tested a separate set of samples using a Fourier Transform Interferometer. The results are included as an appendix. Although the frequency range is higher than will be used on the GBT, the measurements can be expected to place an upper limit on losses at lower frequencies. The average loss at 130 GHz is less than 3% and the maximum is 4.5%. The numbers are reasonably consistent with the 90 GHz measurements.

V. Conclusions

Dissipative loss in the paint samples is negligible at frequencies below 100 GHz or so. Some scattering is observed at the 5% level, but better measurements (e.g., on thicker plates which will remain flat) would need to be made to confirm this and to determine the angular region of scatter.

Phase shifts due to the dielectric should not be a problem even for 4 mil thicknesses up to ~150 GHz.

APPENDIX

NATIONAL PHYSICAL LABORATORY

Teddington Middlesex TW11 0LW England

Certificate of Calibration

THE DETERMINATION OF THE POWER REFLECTION SPECTRA OF SOME PAINTED ALUMINIUM SHEETS

FOR:	National Radio Astronomy Observatory Edgemont Road Charlottesville VA 22903, USA
CUSTOMER REFERENCE:	#POO131
DESCRIPTION:	6 painted sheets, approximately 100 x 100 x 1.7 mm^3

REFERENCE C15/0089

DATE 16 December 1991

SIGNED S Pollitt for Director

CHECKED Elizabeth McNicol

MEASUREMENTS

The normal incidence power reflection spectra of six painted aluminium sheets were determined in the spectral region between 120 and 360 GHz by the technique of Fourier transform spectroscopy. The interferometer used in the measurements was a polarising wire grid instrument with a liquid helium cooled indium antimonide hot electron bolometer as its detector. The spectral resolution was approximately 30 GHz, and the measurement temperature 293 K. The geometry of the interferometer was such that the extreme off axis ray incident on the specimens would have had an angle of incidence of about 2°. The incident radiation was plane polarised.

The measurements were initially made using an alumined glass blank as the reference reflector. The reflection spectrum of this was subsequently determined in a separate comparison against the NPL standard of far infrared reflectivity based on a silicon disc. The calibrated spectrum of the reference reflector was then used to derive the reflection spectra of the specimens from the measurements.

RESULTS

The results of the measurements are shown in figures 1 to 6. Each spectrum represents the average of four independent determinations. The reproducibility of these was such as to suggest a random uncertainty in each average reflection spectra of about 0.01, or less, over most of the measured spectral region.

In addition to the measurements described above, two of the specimens (3.0 and 4.0 mils) had their reflection spectra measured in 4 orientations, for orthogonal orientations of the incident polarisations on both painted surfaces. The results of this are presented in figures 7 and 8. These show significant differences, particularly for the 3.0 mils specimen.

The tabulated values of the spectra shown in figures 1 to 6 are presented in tables 1 to 6.

Fig 1.

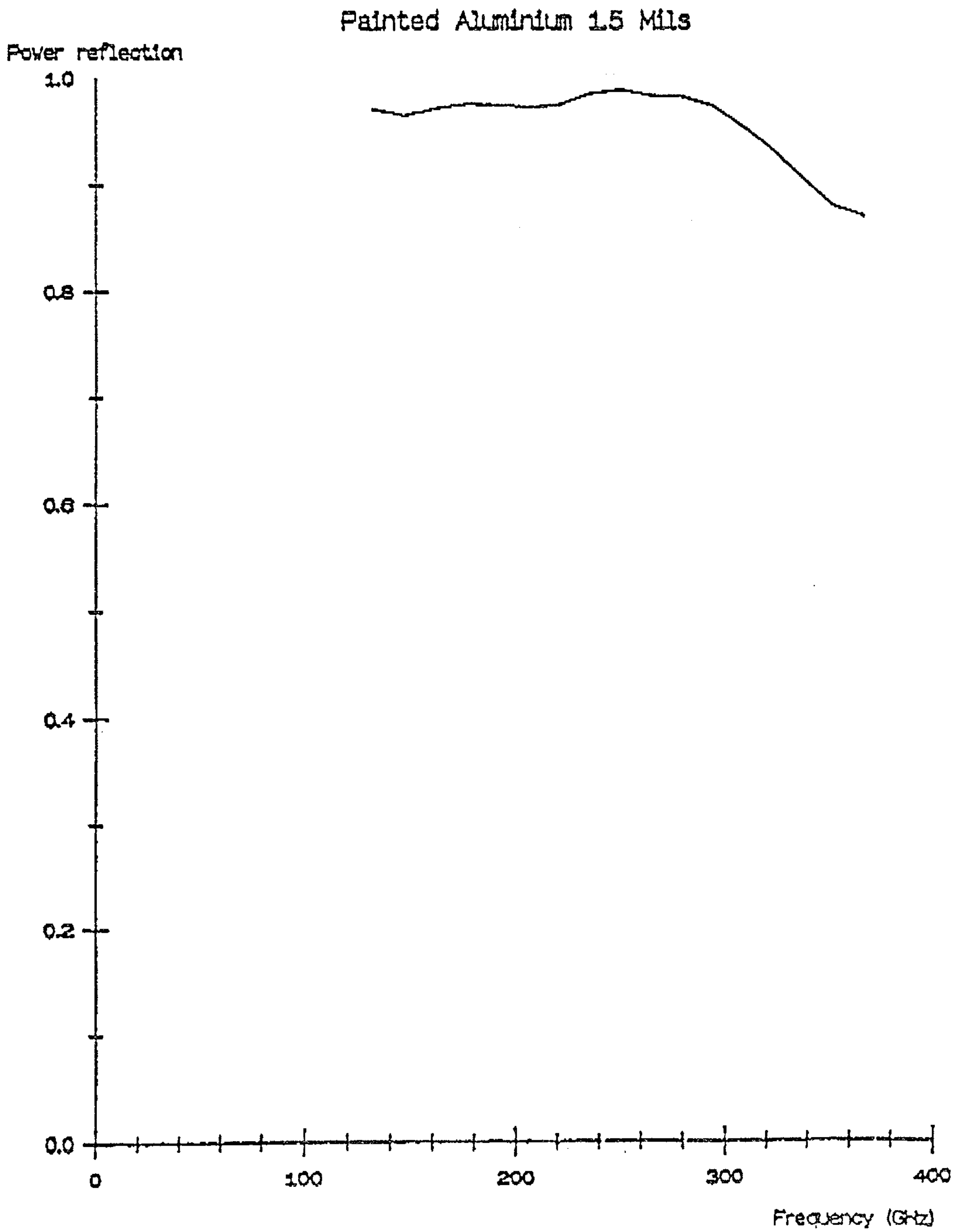

Painted Aluminium 1.5 Mils
Power reflection
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
Frequency (GHz)

Fig 2.

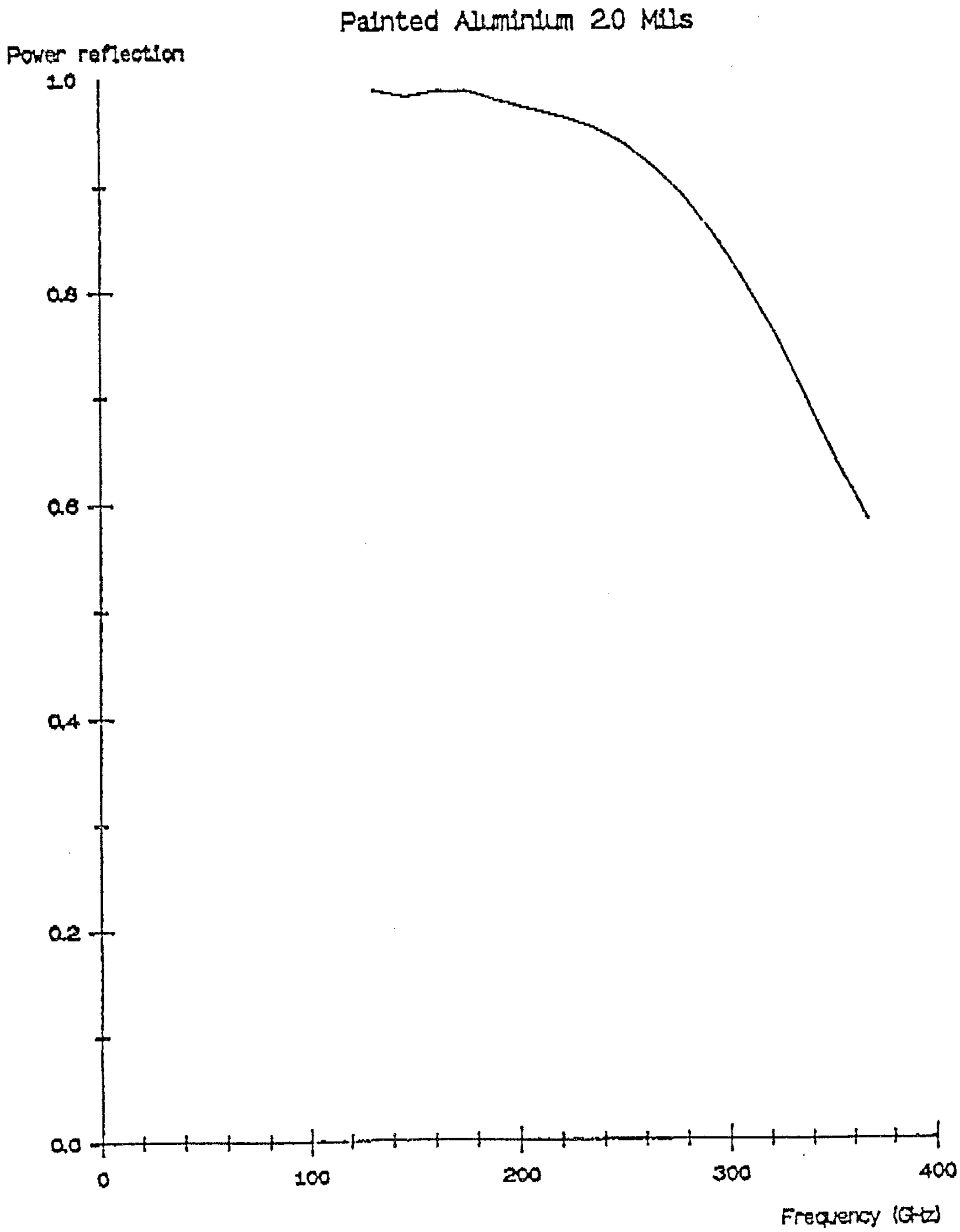

Painted Aluminium 2.0 Mils
Power reflection
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
Frequency (GHz)

Fig 3.

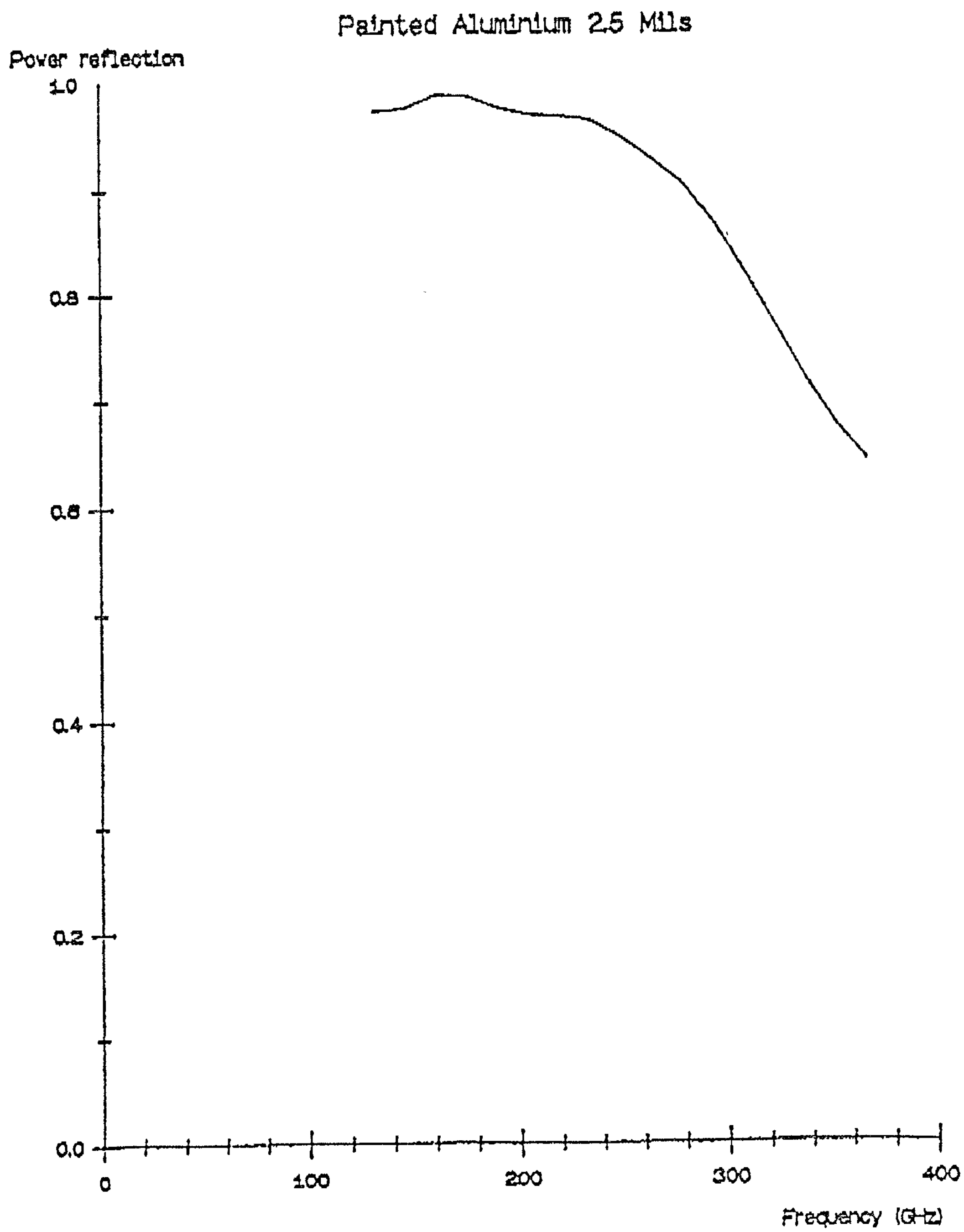

Painted Aluminium 2.5 Mils
Power reflection
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
Frequency (GHz)

Fig 4.

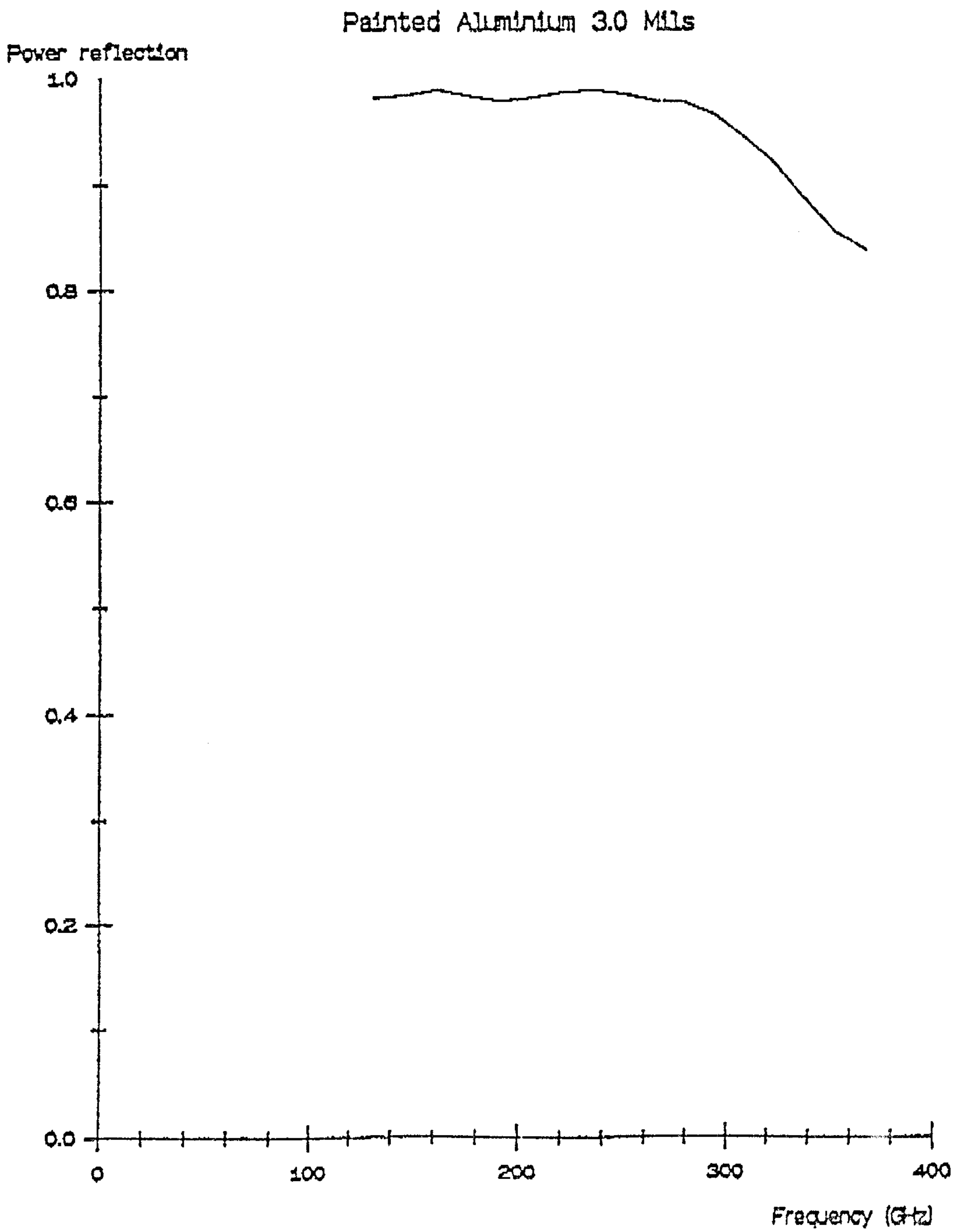

Painted Aluminium 3.0 Mils
Power reflection
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
Frequency (GHz)

Fig 5.

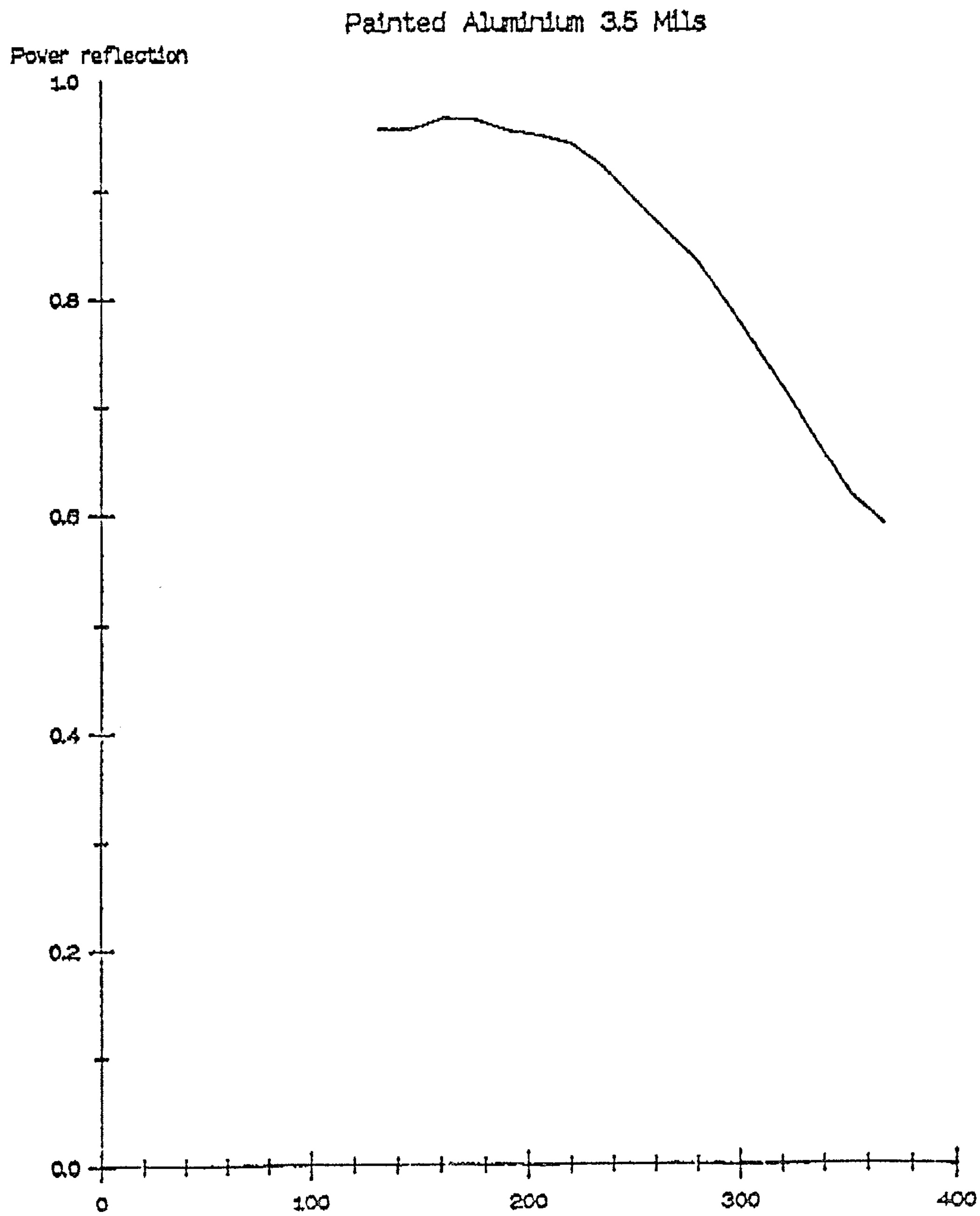
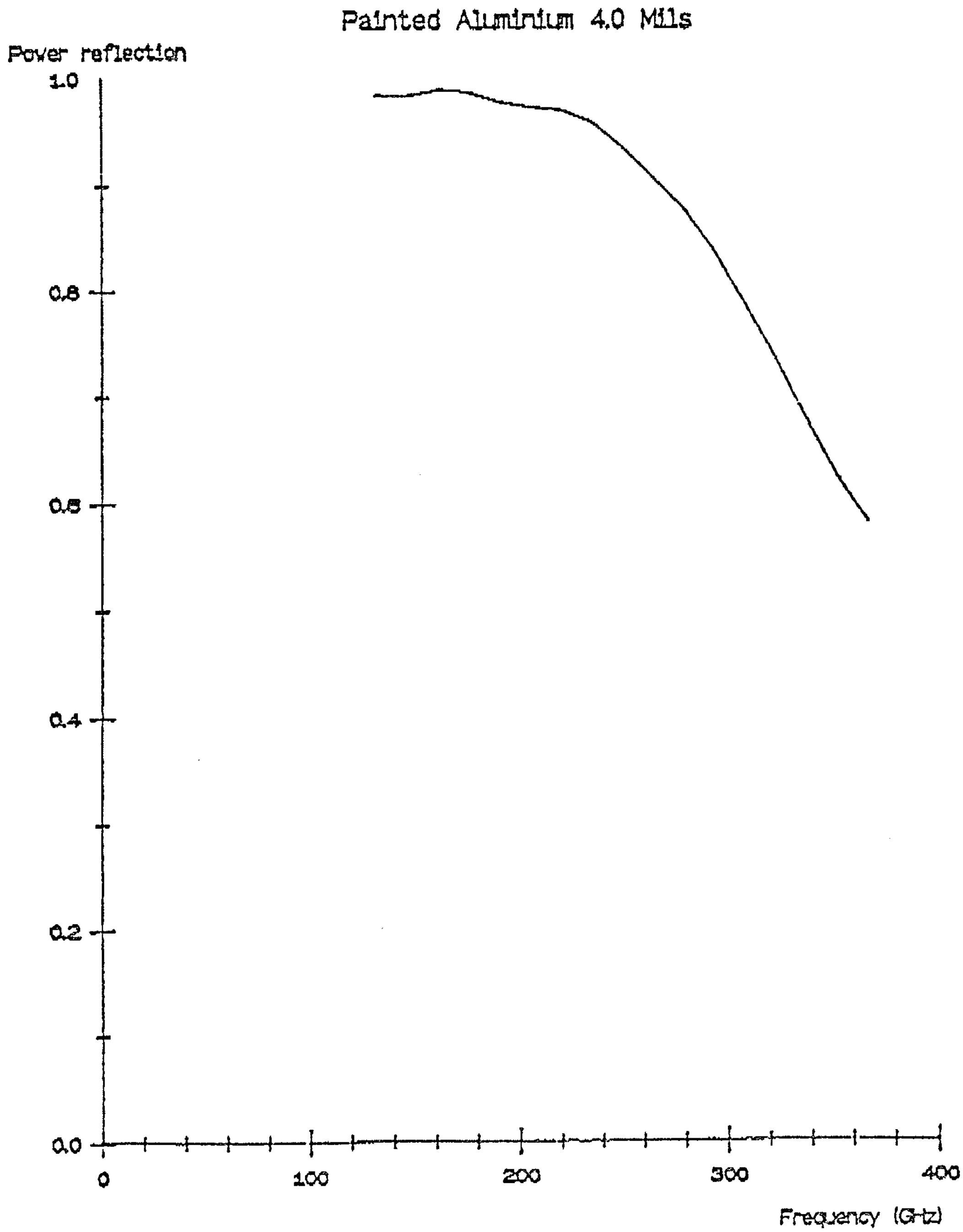

Painted Aluminium 3.5 Mils
Power reflection
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400

Fig 6.



Painted Aluminium 4.0 Mils
Power reflection
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
Frequency (GHz)

——— – same orientation as other measurements

········ – rotated through 90°

—·—·— – reverse side

— — – rotated through 90°

Fig 7.

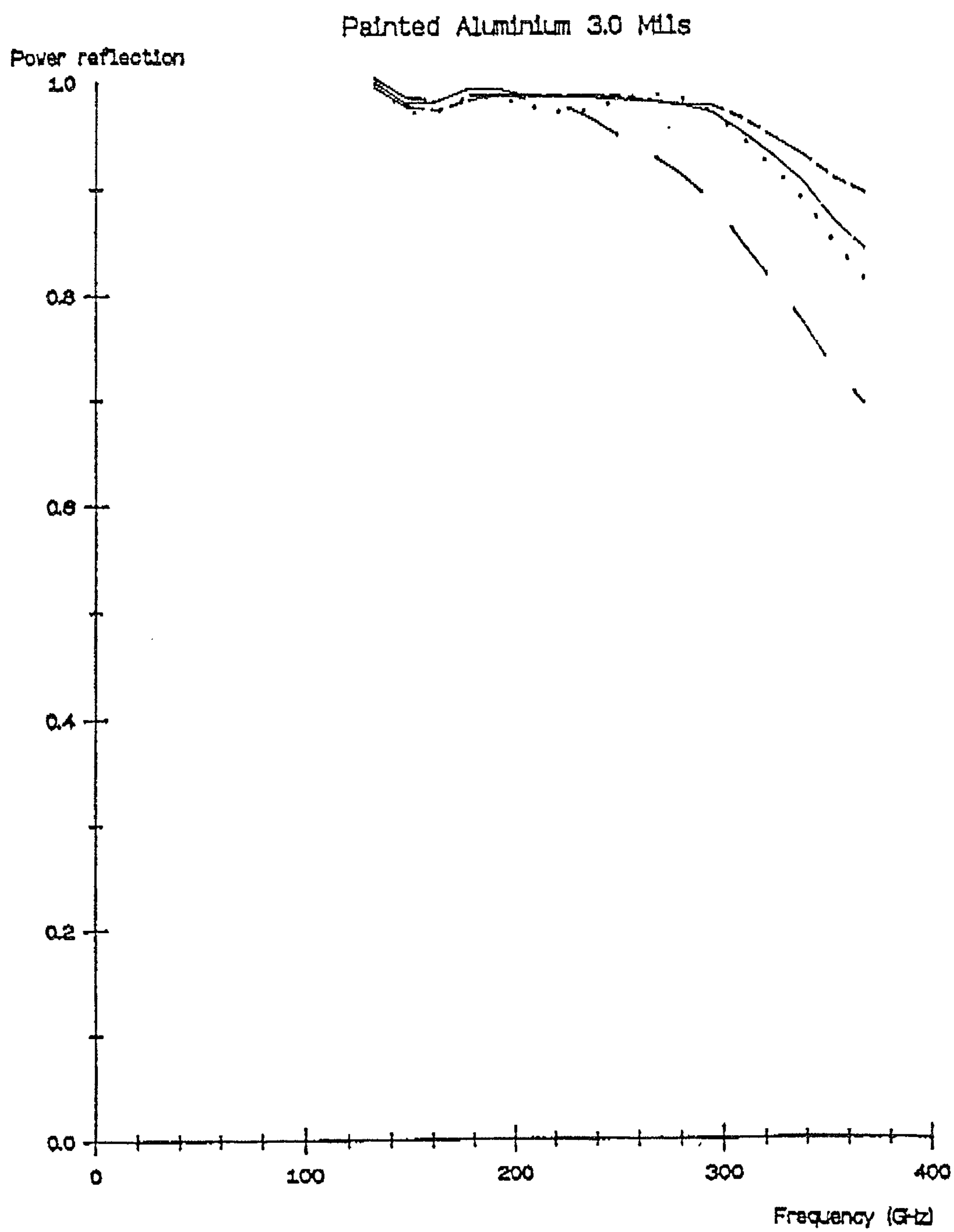


Fig 8.
Same key as fig. 7.

Painted Aluminium 4.0 Mils

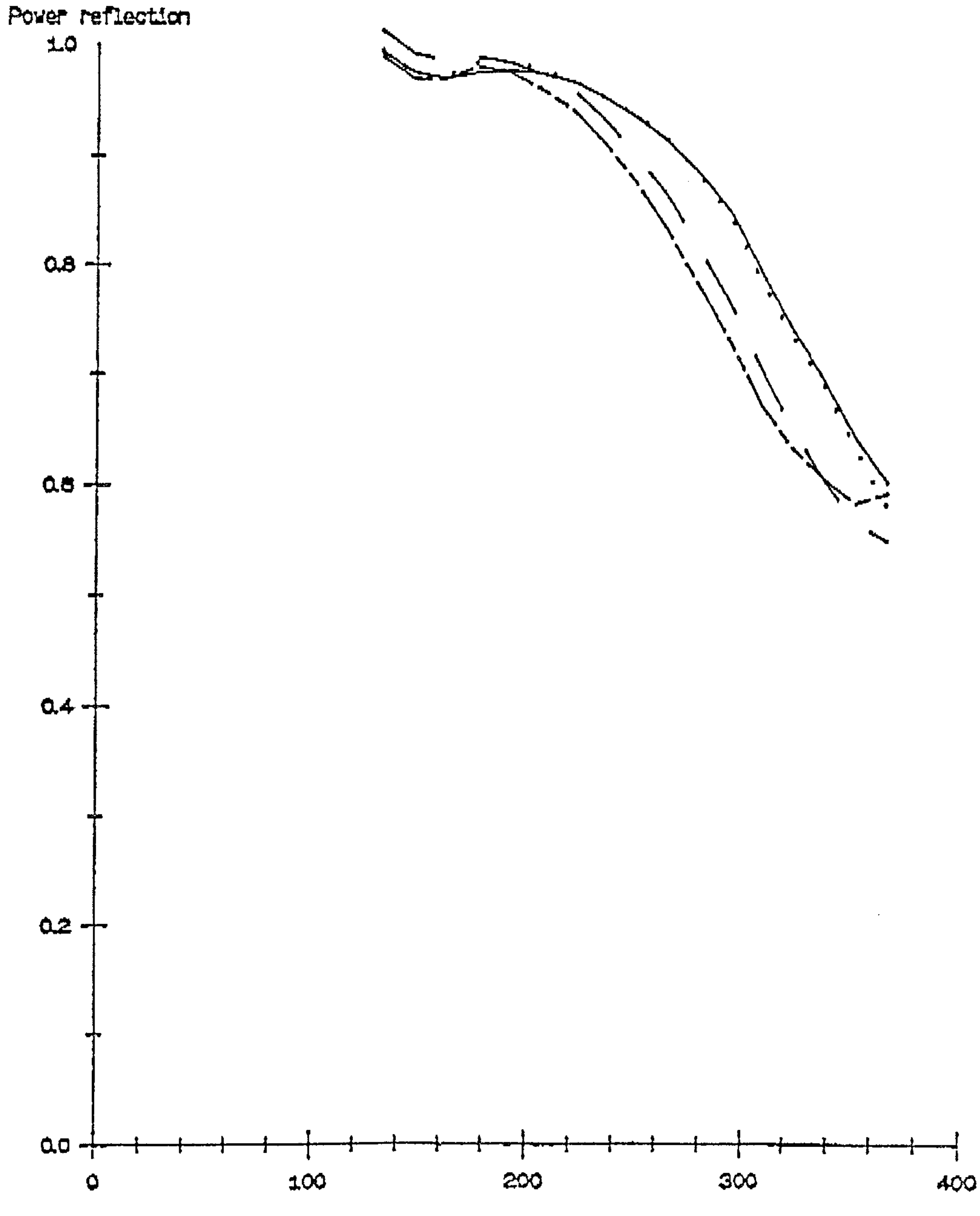


Table 1

Painted Aluminium 1.5 Mils

Frequency (GHz)	power reflection
131.8359	0.96890
146.4844	0.96355
161.1328	0.97051
175.7813	0.97466
190.4297	0.97321
205.0781	0.97112
219.7266	0.97351
234.3750	0.98418
249.0234	0.98790
263.6719	0.98254
278.3203	0.98105
292.9688	0.97309
307.6172	0.95299
322.2656	0.93101
336.9141	0.90408
351.5625	0.87825
366.2109	0.86813

Table 2

Painted Aluminium 2.0 Mils

Frequency (GHz)	power reflection
131.8359	0.98761
146.4844	0.98212
161.1328	0.98773
175.7813	0.98731
190.4297	0.97850
205.0781	0.97039
219.7266	0.96294
234.3750	0.95340
249.0234	0.93896
263.6719	0.91689
278.3203	0.88912
292.9688	0.85082
307.6172	0.80553
322.2656	0.75533
336.9141	0.69598
351.5625	0.63573
366.2109	0.58391

Table 3

Painted Aluminium 2.5 Mils

Frequency (GHz)	power reflection
131.8359	0.97219
146.4844	0.97552
161.1328	0.98770
175.7813	0.98567
190.4297	0.97544
205.0781	0.96863
219.7266	0.96678
234.3750	0.96313
249.0234	0.94801
263.6719	0.92698
278.3203	0.90420
292.9688	0.86738
307.6172	0.81881
322.2656	0.76726
336.9141	0.71729
351.5625	0.67524
366.2109	0.64274

Table 4

Painted Aluminium 3.0 Mils

Frequency (GHz)	power reflection
131.8359	0.98137
146.4844	0.98336
161.1328	0.98836
175.7813	0.98248
190.4297	0.97767
205.0781	0.98084
219.7266	0.98600
234.3750	0.98823
249.0234	0.98432
263.6719	0.97828
278.3203	0.97698
292.9688	0.96524
307.6172	0.94407
322.2656	0.92034
336.9141	0.88654
351.5625	0.85416
366.2109	0.83693

Table 5

Painted Aluminium 3.5 Mils

Frequency (GHz)	power reflection
131.8359	0.95473
146.4844	0.95538
161.1328	0.96521
175.7813	0.96293
190.4297	0.95348
205.0781	0.94866
219.7266	0.94145
234.3750	0.92124
249.0234	0.89193
263.6719	0.86276
278.3203	0.83548
292.9688	0.79458
307.6172	0.74878
322.2656	0.70684
336.9141	0.66077
351.5625	0.61634
366.2109	0.58991

Table 6

Painted Aluminium 4.0 Mils

Frequency (GHz)	power reflection
131.8359	0.98280
146.4844	0.98238
161.1328	0.98792
175.7813	0.98515
190.4297	0.97606
205.0781	0.97121
219.7266	0.96840
234.3750	0.95762
249.0234	0.93465
263.6719	0.90668
278.3203	0.87730
292.9688	0.83667
307.6172	0.78688
322.2656	0.73314
336.9141	0.67690
351.5625	0.62285
366.2109	0.57994