Measurement of different materials for a WR-10 waveguide vacuum window.

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TABLE OF CONTENTS

1. Introduction

The CAY amplifiers laboratory is developing a measurement system of cryogenic amplifiers for the 70-115 GHz band. The input and output ports of the cryostat will be vacuum windows in WR-10 waveguide.

The hermetic WR-10 feedthrough with part number 10-1662 (Figure 1) has been acquired from the Aerowave Company (through Radar System Technology Inc. supplier). This feedthrough is a simplified version of the one designed for ALMA[1]. The feedthrough material is brass plated with 0.1 µm of rhodium over 1 µm of gold. It does not contain a vacuum window.

Figure 1. Hermetic WR-10 feedthrough, p/n 10-1662, from the Aerowave company.

The vacuum window consists of a sheet of Mylar (typically, although it is possible to use other materials sheets) clamped between the feedthrough and a flange with an O-ring seal. This vacuum window must have:

1) Low gas permeability: the He leak rate must be acceptable to keep the cryostat vacuum level needed.
2) Low signal losses: The insertion loss should be low and without sharp resonances at any frequency in the band. The reflection coefficient should be low as well.

The goal of this report is to select the best suitable option for the vacuum window, comparing the performance of different materials and sheet thickness available.

[1] ALMA Memo 536. "*WR-10 Waveguide Vacuum Feedthrough for the ALMA Band-6 Cartridge*". G. A. Ediss, N. Horner, F. Johnson, D. Koller, A. R. Kerr. NRAO. 7 Sept 2005.

The different options tested are presented in the Table 1:

Material	*Permitivity*	*Thickness (µm)*
Mica	5.7	50
Mylar	3	13
Mylar	3	25
Mylar	3	70
Kapton	3.1-3.4	58

Table 1.Characteristics of the materials measured.

2. Measured performance of different vacuum windows.

The characterization of the different materials for the vacuum windows was performed using the Scalar R/T setup, explained in detail in the technical report CDT 2015-4[2].

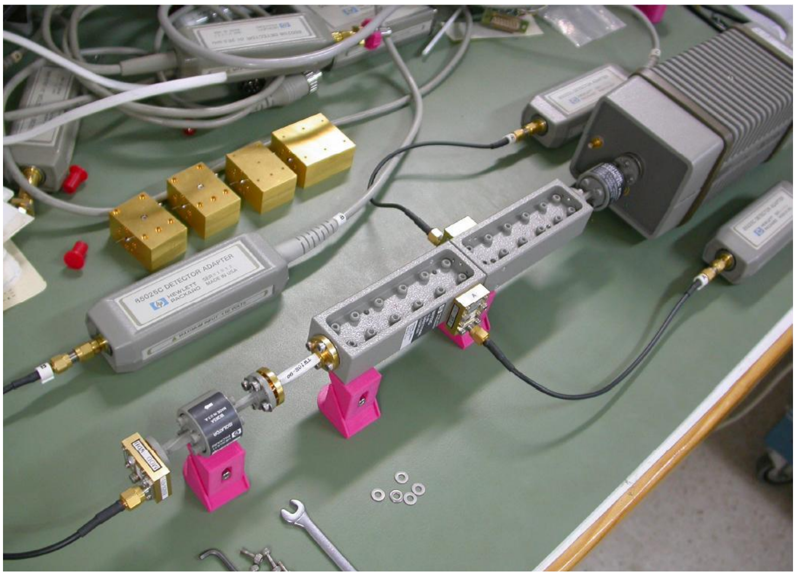

Figure 2. Setup for Scalar R/T Measurements in the Extended W Band (70-115 GHz).

The thru calibration of the system is performed with a straight section of waveguide (2”) and the Aerowave 10-1662 piece in the signal path but WITHOUT any vacuum window sheet inserted in between (setup shown in Figure 3). In this way, the insertion loss of measurements will show only the effects of the different materials inserted. The results of this thru calibration are shown in Figure 4: An insertion loss of 0 dB and a reflection better than -30 dB in the 75-115 GHz band. The results obtained with the materials tested are presented in figures 5-9.

[2] *“Configuration of the Laboratory Setup for Scalar R/T Measurements in the Extended W Band (70-115 GHz)”*, J.D. Gallego, I. Malo, I. López, C. Diez.

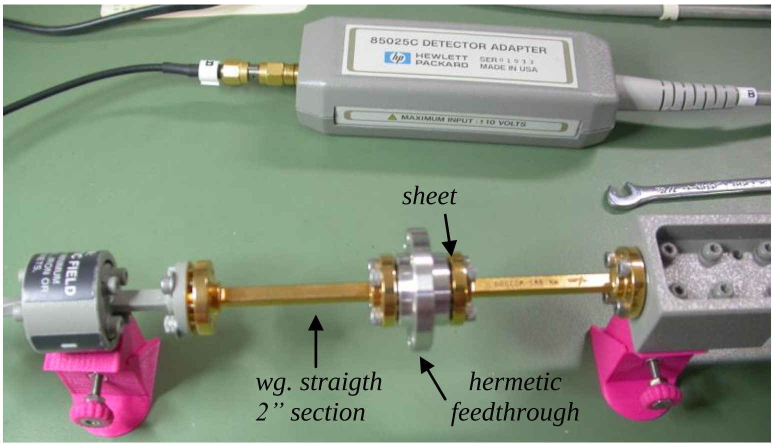

Figure 3. Components for the measurement of the vacuum windows.

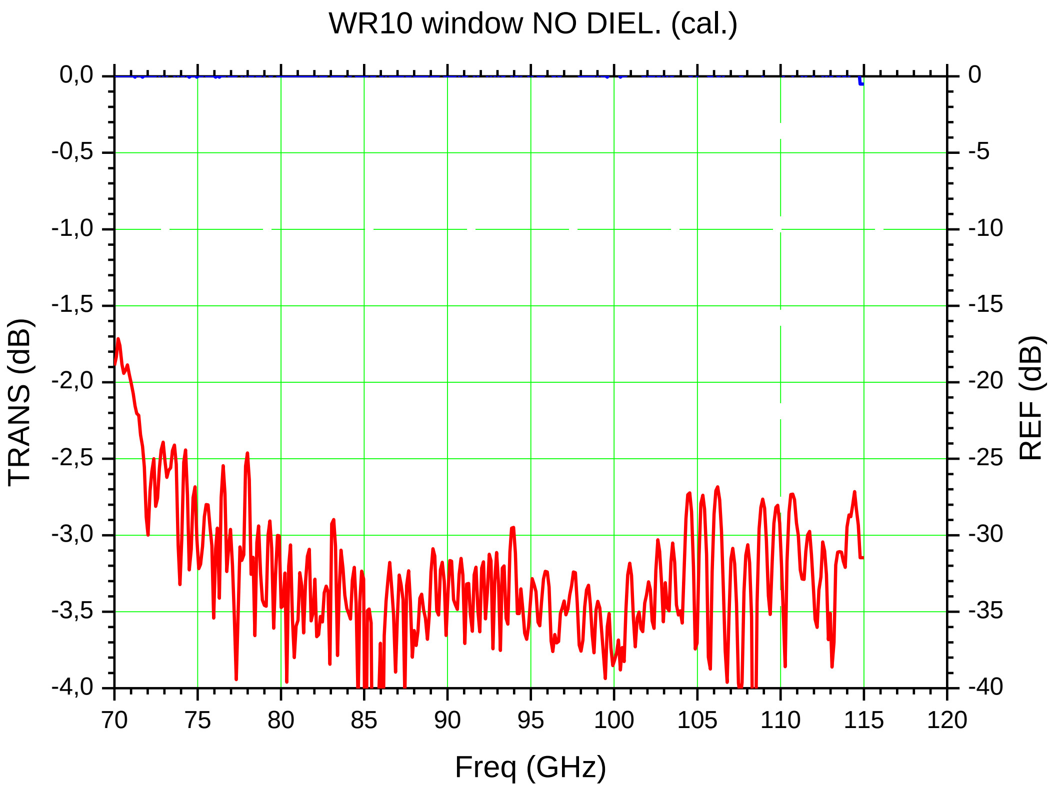

Figure 4. Transmission and reflection of the hermetic feedthrough and the straight waveguide without any vacuum window (sheet) after the thru calibration.

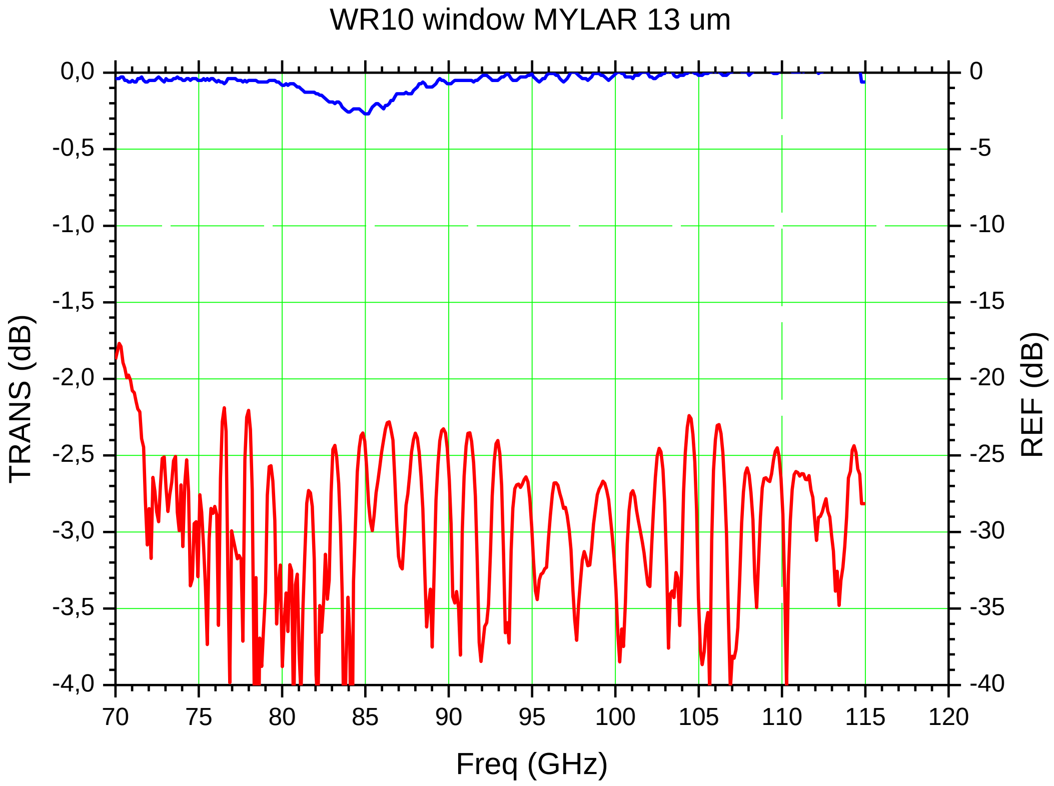

Figure 5. Transmission and reflection of a 13 µm of Mylar as a vacuum window.

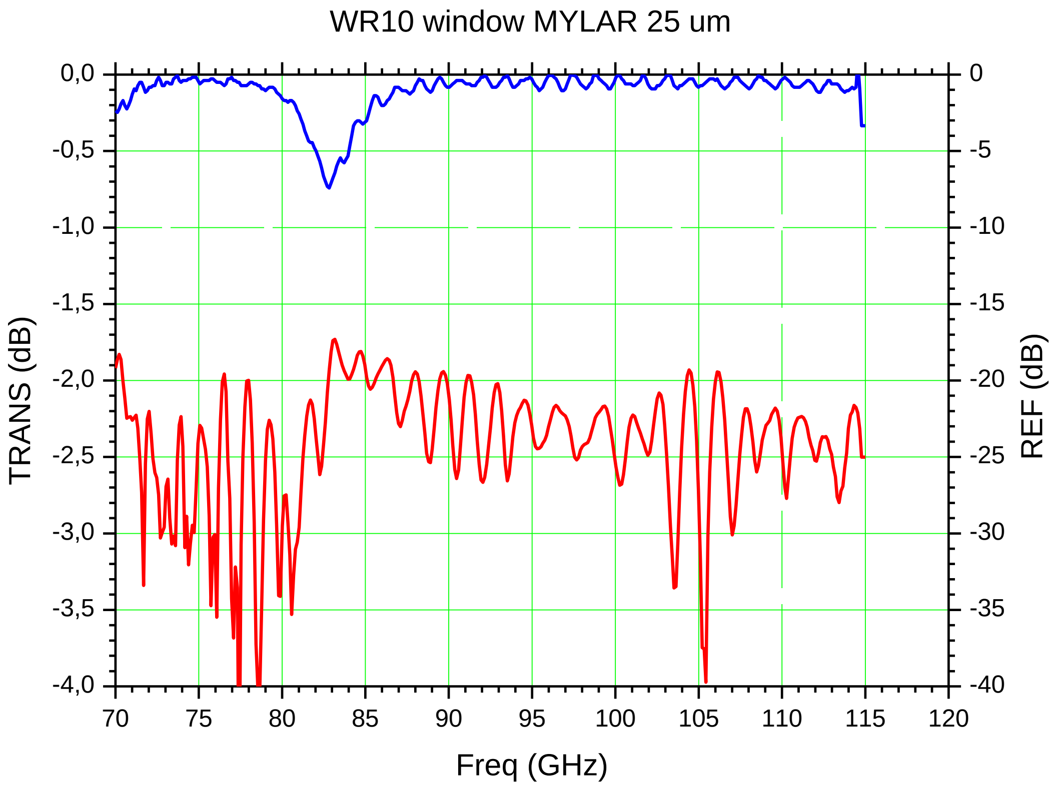

Figure 6. Transmission and reflection of a 25 µm of Mylar as a vacuum window.

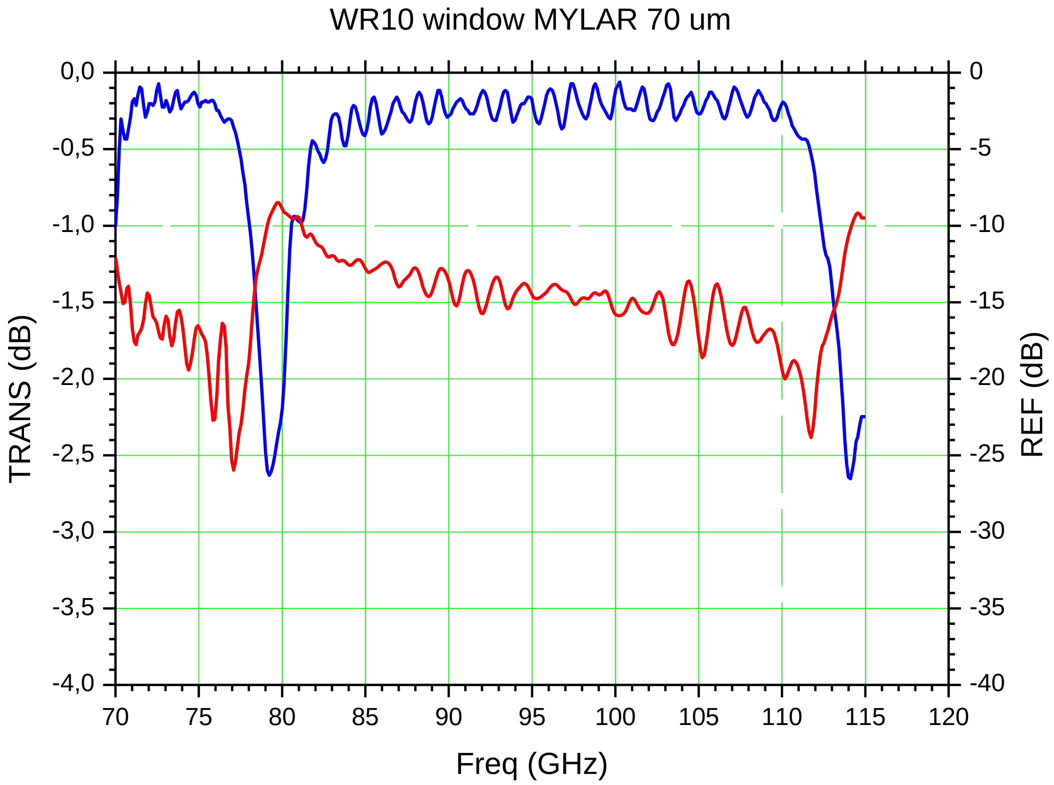

Figure 7. Transmission and reflection of a 70 µm of Mylar as a vacuum window.

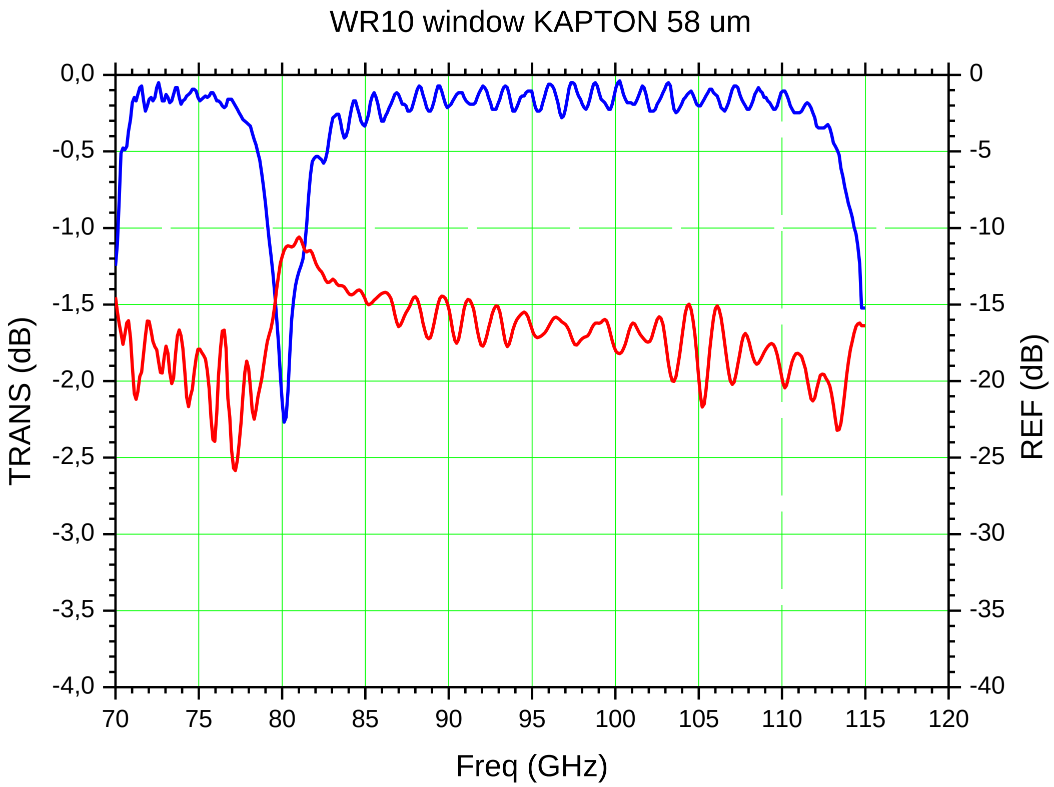

Figure 8. Transmission and reflection of a 58 µm of Kapton as a vacuum window.

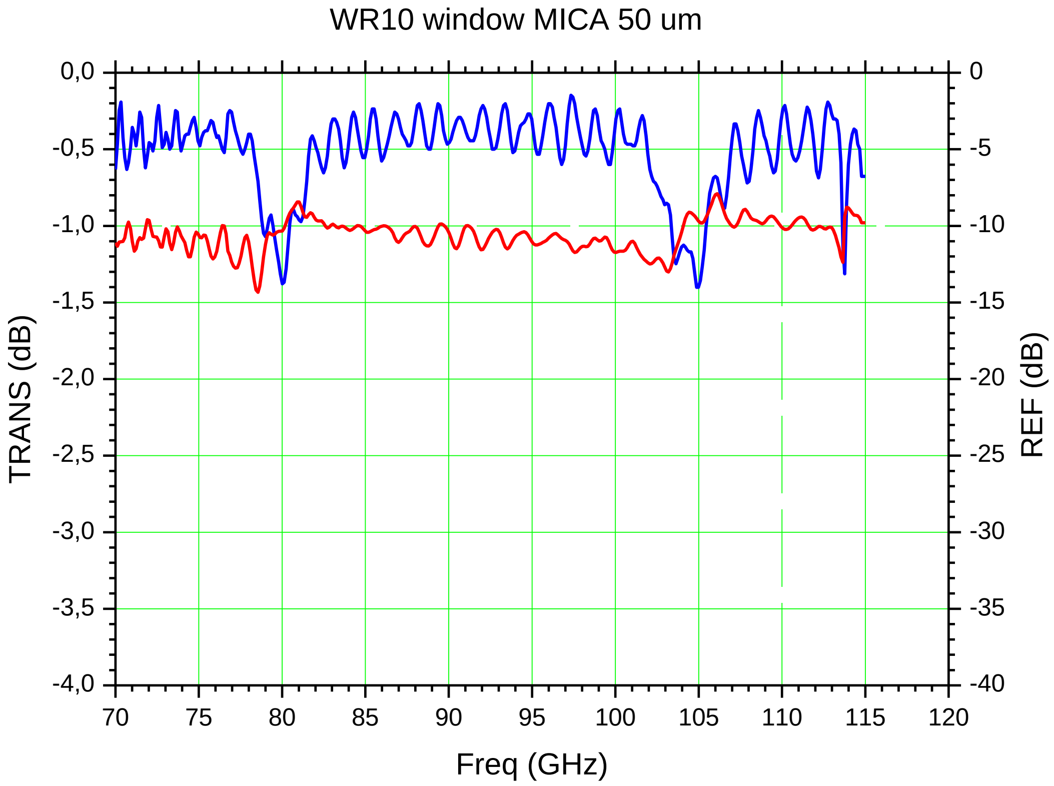

Figure 9. Transmission and reflection of a 50 µm of Mica as a vacuum window.

As shown in figures 5 to 9, one or two undesirable "dips" appear in the transmission. The effect is more pronounced for larger thickness of the dielectric window. To learn more of this effect, several additional tests were performed in a different set-up with a PNAx:

a) Measurement of the 25 µm Mylar window between two straight sections of waveguide (one of 1" and one of 2") with regular waveguide flanges which do not have the cavity for the o-ring (Figure 10). The "dips" are still present so the cavity for the o-ring does not appear to be the cause (at least not the main cause) of this problem. Note that the straight sections are not calibrated, so their losses are added to the performance of the window in the Figure 10.

b) Measurement of the 25 µm Mylar window between the Aerowave 10-1662 piece, which has a flat flange face (and include the o-ring groove), and a straight 1" section of Cu waveguide with a flat flange face in contact with the Mylar. The "dip" in the transmission is still present, so the cylindrical protrusion of regular waveguide flanges does not appear to be the cause the problem (Figure 11).

c) Measurements of windows of 25 µm Mylar but with different diameters of the window show a similar performance. The size of the window does not change the frequency of the "dip" neither the performance of the window.

Finally, Figure 12 presents the comparison of the measurement of a 13 µm Mylar window, between the Aerowave 10-1662 piece and the straight 1" Cu waveguide, versus a 25 µm Mylar window in the same position. This measurement shows the losses of the feedthrough, window and waveguide.

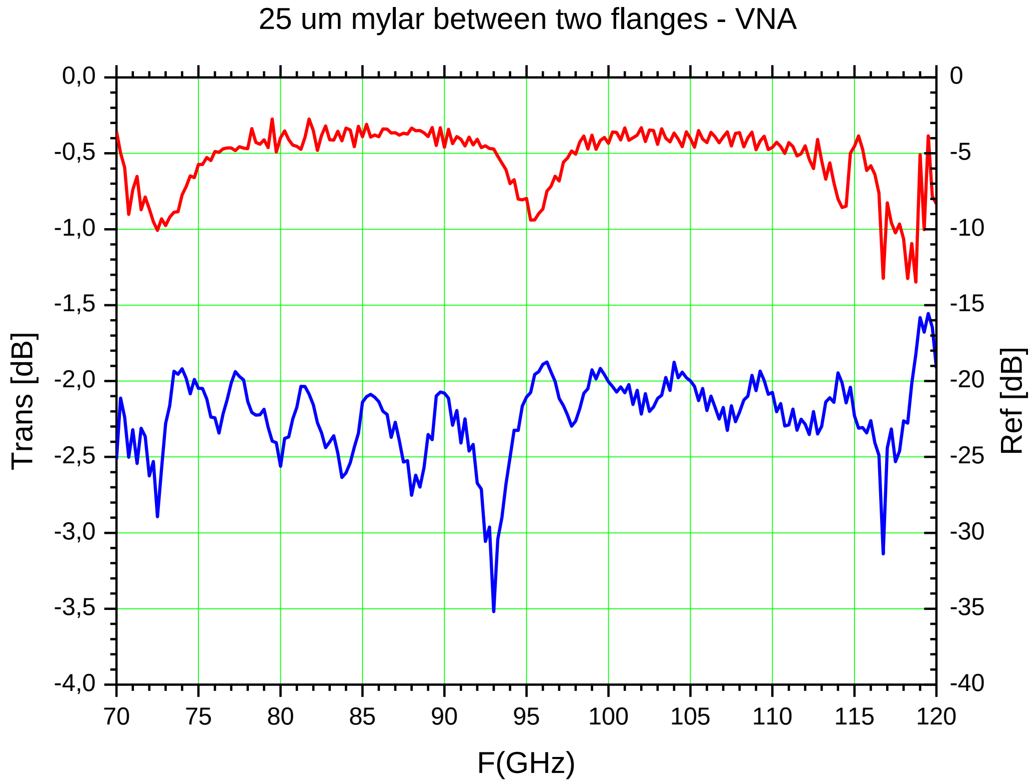

Figure 10. *25 µm Mylar sheet between two regular waveguide flanges (without o-ring cavity). Note that the losses of the two straight sections of waveguide (one of 1" and one of 2") used in the measurement are added to the performance of the window.*

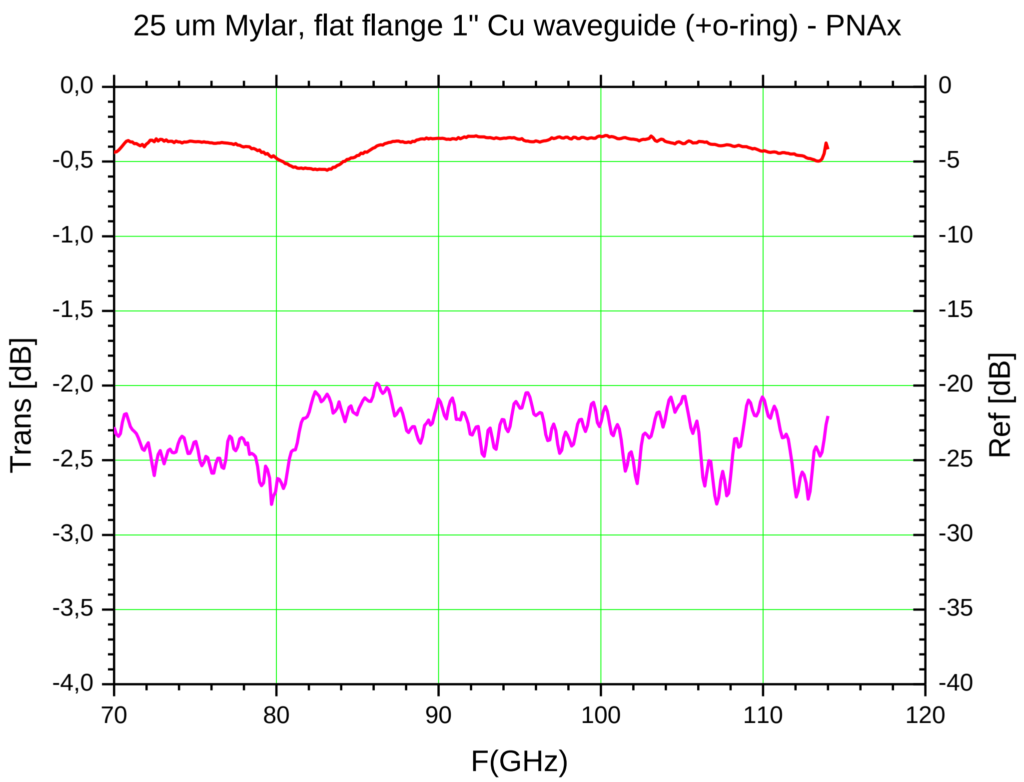

Figure 11. 25 µm Mylar sheet between two flat face flanges.

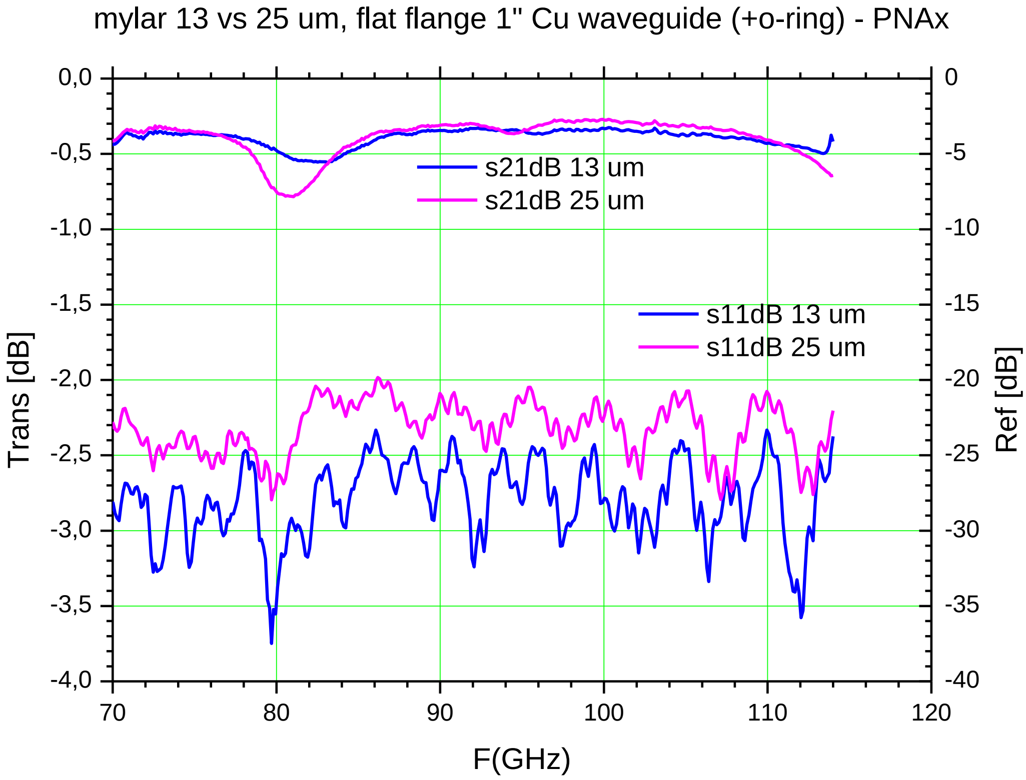

Figure 12. Comparison of a 13 vs 25 µm Mylar windows between flat flange faces.

3. Gas permeability

The hermetic WR-10 feedthrough with the 13 µm Mylar sheet was mounted in a window of the 1020-1 Yebes cryostat. The window was checked with an ALCATEL ASM-121-H He leak detector. The value obtained after flushing the outer port with pure He gas was $2 \cdot 10^{-9}$ mbar l/s, which was considered very low.

4. Mechanical performance.

The 13 µm Mylar sheet is very fragile mechanically. We were concern about possible catastrophic failures which may cause implosions and damage to the cooled amplifiers To asset the robustness of the system, a number of successive fast cycles (seven) of filling/emptying the cryostat were performed with the 13 µm Mylar window mounted. No failure was produced.

5. Conclusion.

A vacuum window of 13 µm of Mylar was considered the best option due to its better electrical performance and the acceptable leaking rate and robustness. It was decided to use this material with VITON O-rings in the final version of the measuring cryostat.