# ALMA Memo No. 340

# Measurements of Commercial Vacuum Windows for ALMA Bands 3 and 6

5 December 2000

G. A. Ediss*, S.-K. Pan*, J. Effland* and T. Globus†

*National Radio Astronomy Observatory, Charlottesville, VA 22903

†Dept. of EE, University of Virginia, Charlottesville, VA 22903

Measurements have been made of commercial vacuum windows [1] designed for ALMA bands 3 and 6 (84-116 GHz and 211-275 GHz, respectively). The samples are made of 0.226 inch thick quartz with two matching layers of plastic attached to each face. One sample for each band was supplied (QMC100 for band 3 and QMC230 for band 6), and both have been measured at 75-110 GHz with a HP 8510 vector network analyzer in time domain mode [2], at 216-300 GHz in front of a cooled SIS receiver, and between 2 and 15 wavenumbers (60-450 GHz) at low resolution (0.25 wavenumbers, 7.5 GHz) with a Bruker IFS 66V Fourier Transform Spectrometer (FTS).

Figures 1 and 2 show the transmission measured on a FTS system by QMC Instruments (also delivered with the samples); 1 wavenumber is equivalent to 30 GHz. Both figures also show the measured FTS transmission of the uncoated quartz; the peaks and valleys do not reach the expected values as the sample is inserted into a F#3 beam and the reflections from the two surfaces do not completely interfere. These plots indicate that the in-band transmission is better than 97%.

## Time Domain Measurements

The system and measurement details are given in ALMA Memo No. 295 [2] and will not be repeated here. Figures 3 and 4 show the transmission and reflection of window QMC100. The ripple in the transmission curve is probably from residual reflections in the lenses which cannot be totally removed in transmission measurements. The ripple is also seen in Figure 5, NRAO-fabricated window 39q [3], which is also designed for band 3. Figures 6 and 7 show the transmission and reflection of window QMC230.

## 216-300 GHz Measurements

Measurements of the receiver noise temperature were made with and without the windows placed in front of the dewar. The change in noise temperature is then converted into a loss (see [4]). Figure 8 shows the loss of a 0.226 inch thick piece of uncoated quartz, the two QMC windows, and the NRAO window 39q over the range 216 to 300 GHz. The samples were placed perpendicular to the beam. The loss of the out-of-band windows and the uncoated quartz does not rise to the expected level (40%) at the interference maxima. As the surface reflections are terminated somewhere in the dewar at a low temperature, the 8 GHz narrow band IF has little effect. The windows were then tilted 15 degrees to the beam so that some of the reflected power would be terminated at room temperature. The new measurements for QMC230 and the uncoated quartz are shown in Figure 9. The curve for the dewar window shows the loss calculated for two successive measurements of the receiver noise temperature without any samples, and shows a repeatability of less than 1% for the measurements. Further spot frequency measurements with the samples tilted at 45 degrees to the beam showed higher added noise and a frequency shift of the maxima as expected for a Fabry-Perot tilted perpendicularly to the beam [5].

## FTS Measurements

Measurements were made over the frequency range 60 to 450 GHz using a Bruker IFS 66V Fourier transform spectrometer. This spectrometer normally only operates down to 240 GHz but its useful range was extended to lower frequencies with an external source. The resolution of the FTS is 0.25 wavenumbers (7 GHz) which smears out any fine structure in the measured spectra. Figure 10 shows the measured transmission of the QMC100 and NRAO 39q windows. Figure 11 gives two successive measurements of the transmission of window QMC230.

## Conclusion

The measurements made here confirm those made by the manufacturer of the QMC100 (ALMA band 3) and QMC230 (ALMA band 6) windows, and show that the in-band loss (absorption and reflection) of the windows is of order of 2-5% over the whole band. Thus, at least one commercial source has been found for vacuum windows for ALMA receivers. The manufacturer believes that they can supply similar windows for all ALMA bands.

## References

[1] QMC Instruments Ltd, Mile End Road, London, UK.
Http://qmciworks.ph.qmw.ac.uk/homepage.htm

[2] G. A. Ediss, A. R. Kerr and D. Koller, “Measurements of quasi-optical windows with the HP 8510," ALMA Memo No. 295 (3/3/2000).
Http://www.alma.nrao.edu/memos/html-memos/abstracts/abs295.html

[3] D. Koller in preparation.

[4] A. R. Kerr, N. Bailey, D. E. Boyd and N. Horner, “A study of materials for a broadband millimeter-wave quasi-optical vacuum window,” ALMA Memo No. 90 (8/21/1992).
http://www.alma.nrao.edu/memos/html-memos/abstracts/abs090.html

[5] M. Born and E. Wolf, *Principles of Optics*, Oxford: Pergamon Press, 1965.

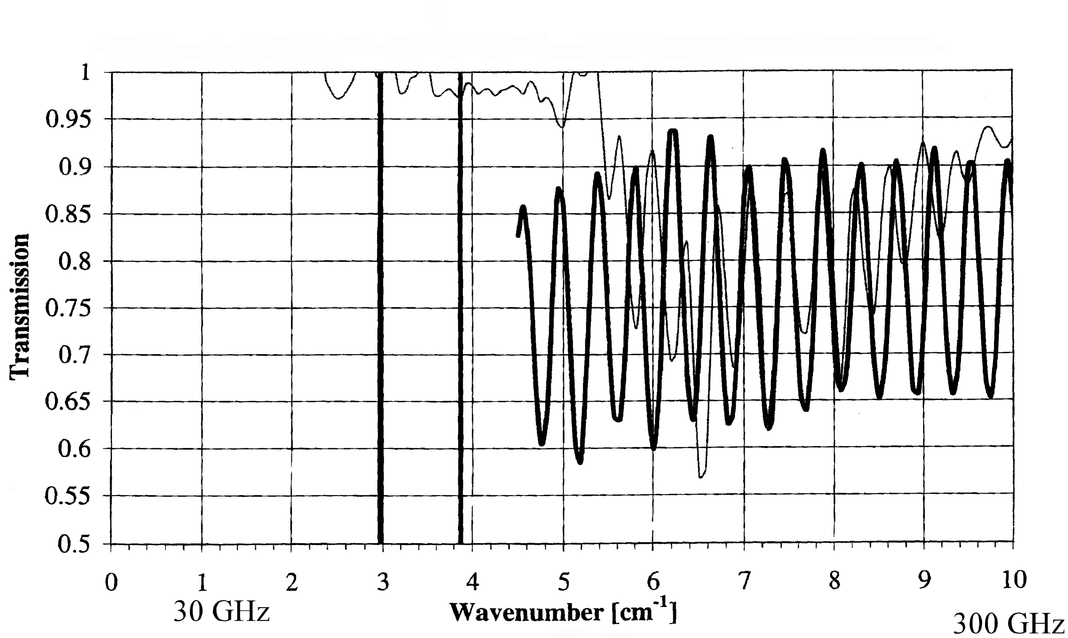


**Figure 1**. Manufacturer-supplied data for Z-cut quartz with and without anti-reflection coating for ALMA band 3 (window QMC100).

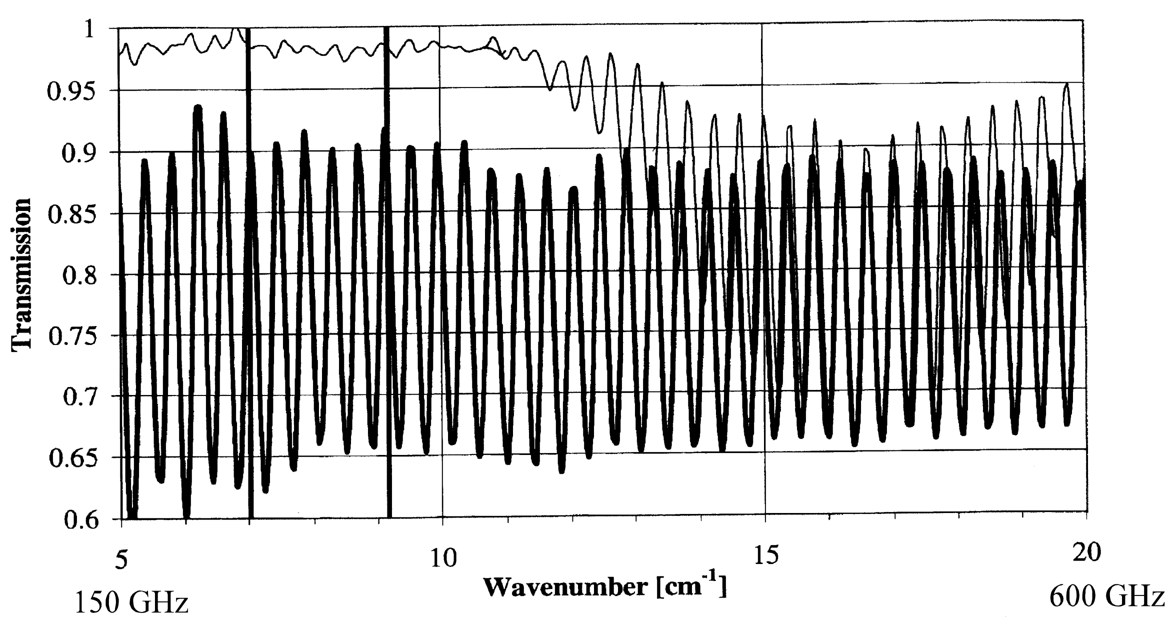


**Figure 2**. Manufacturer-supplied data for Z-cut quartz with and without anti-reflection coating for ALMA band 6 (window QMC230).

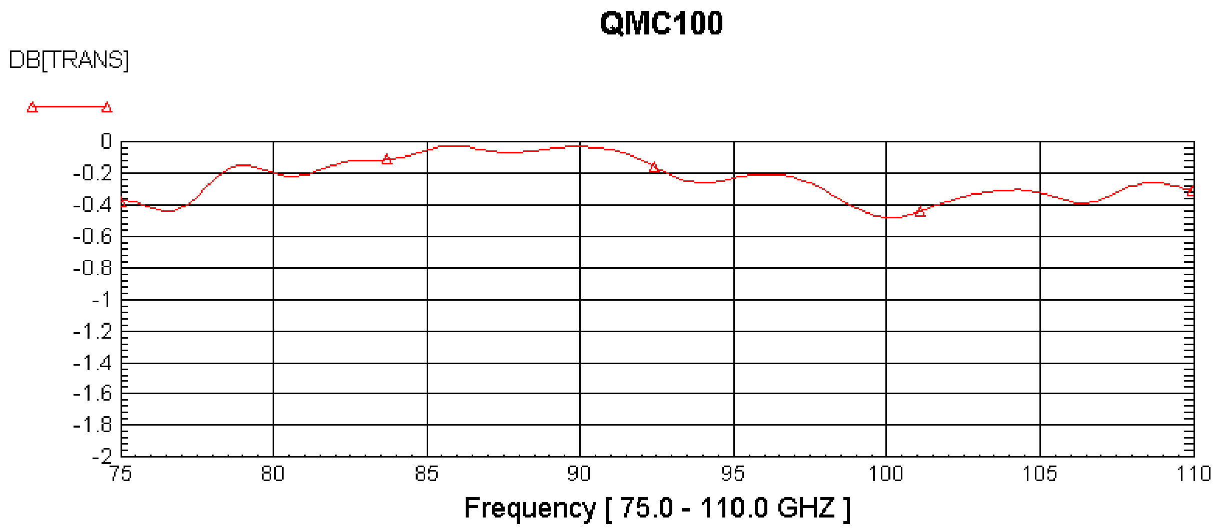


**Figure 3**. Time domain transmission measurement of window QMC100 (ALMA band 3).

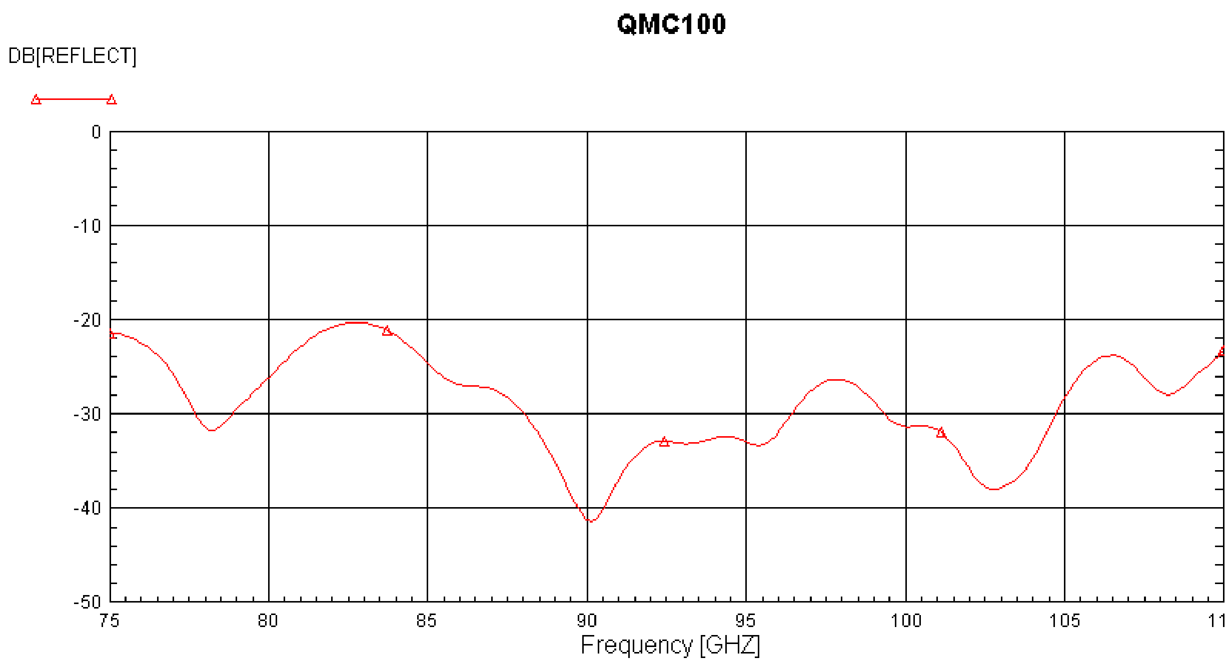


**Figure 4**. Time domain reflection measurement of window QMC100 (ALMA band 3).

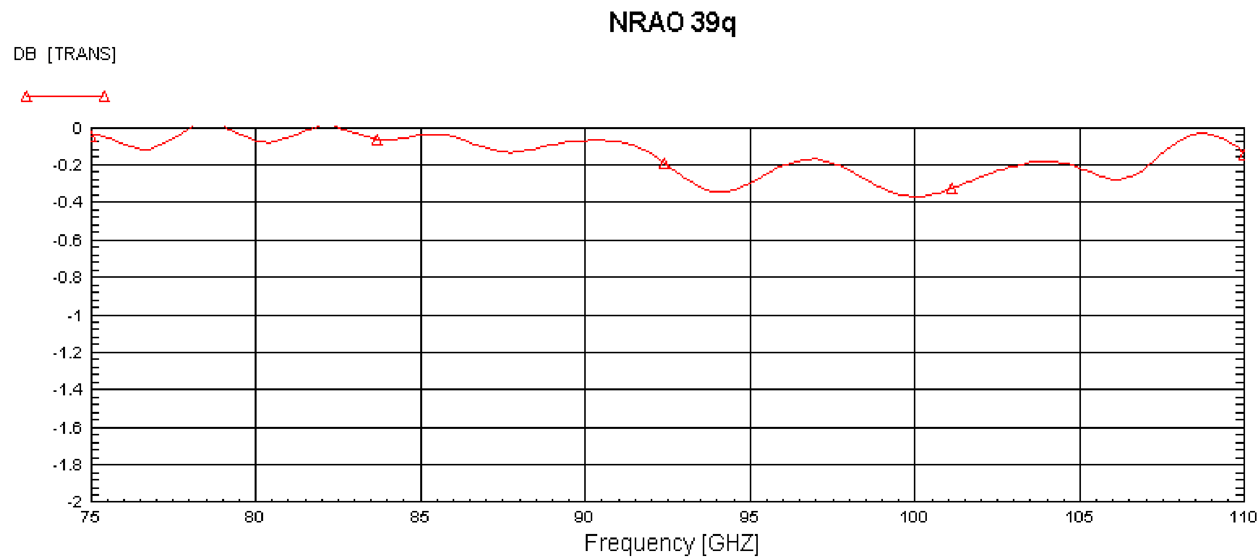


**Figure 5**. Time domain transmission measurement of NRAO window 39q.

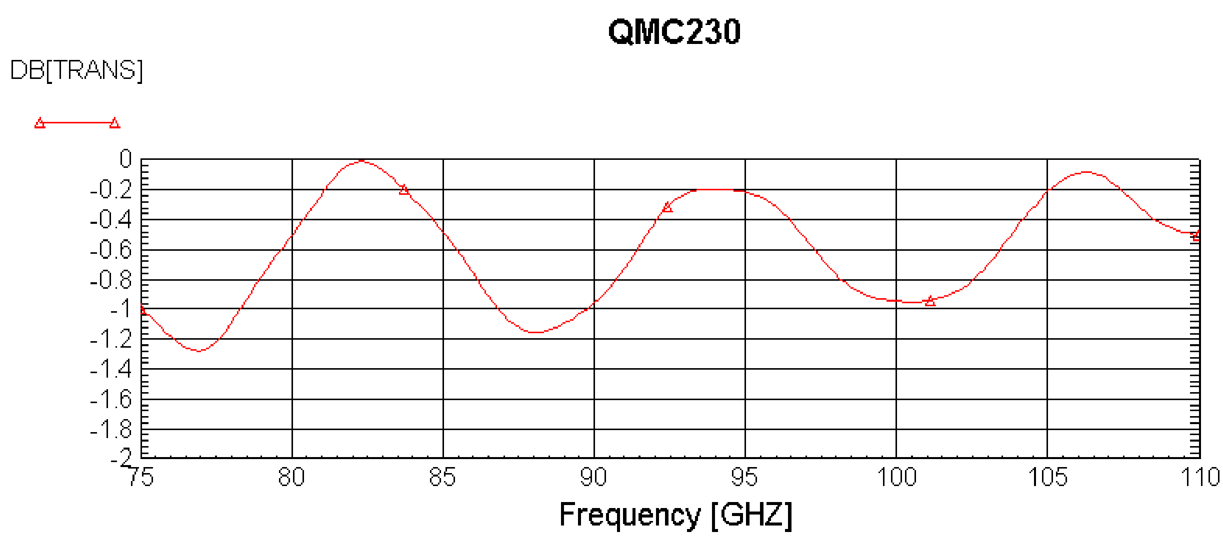


**Figure 6**. Time domain transmission measurement of window QMC230 (ALMA band 6).

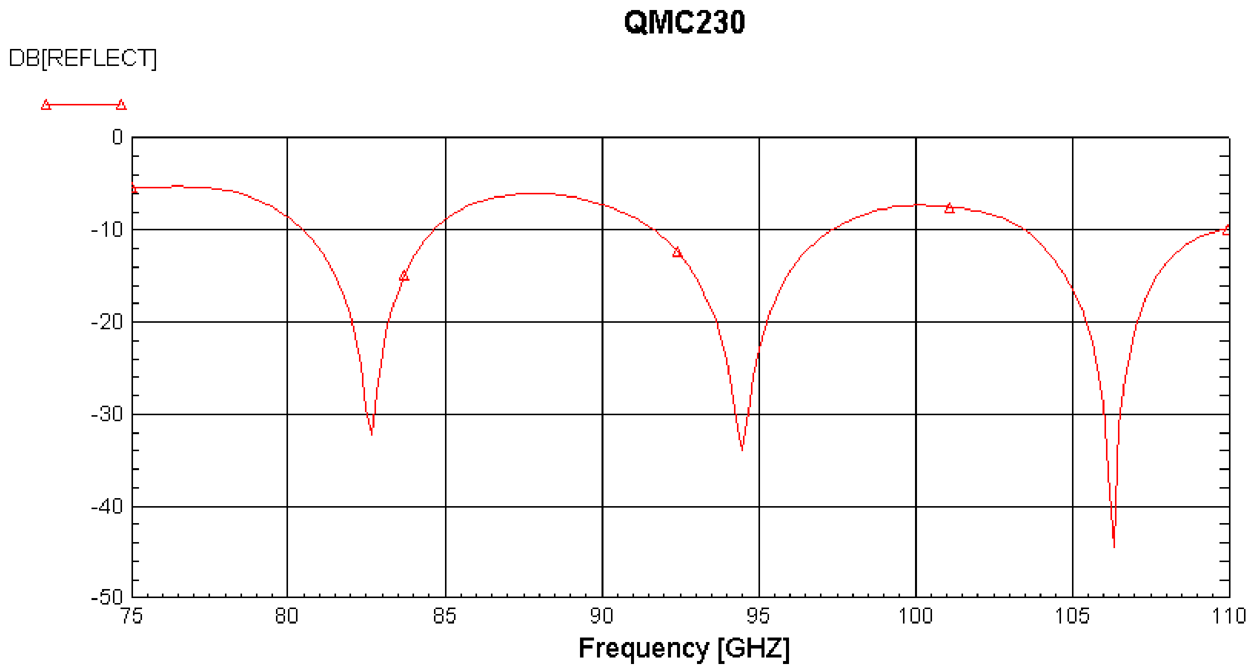


**Figure 7**. Time domain reflection measurement of window QMC230 (ALMA band 6).

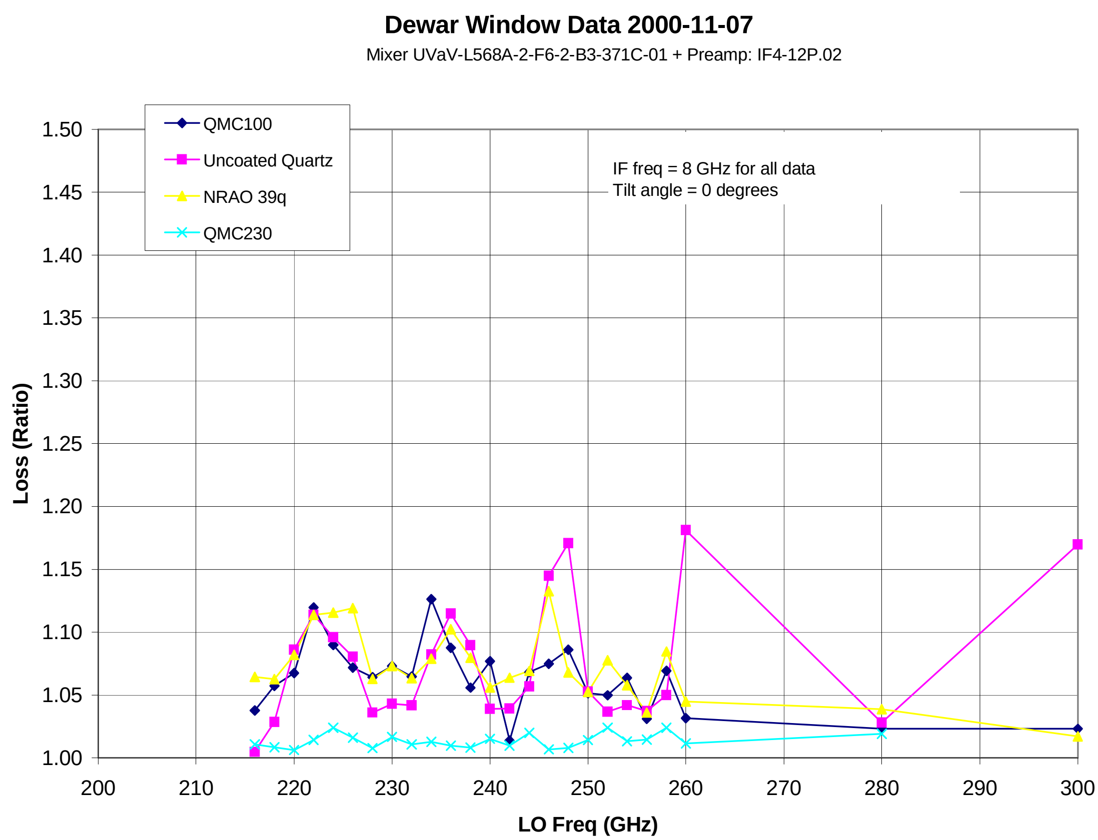


**Figure 8**. Measured losses for various samples in front of a 216-300 GHz SIS receiver, tilt angle 0 degrees.

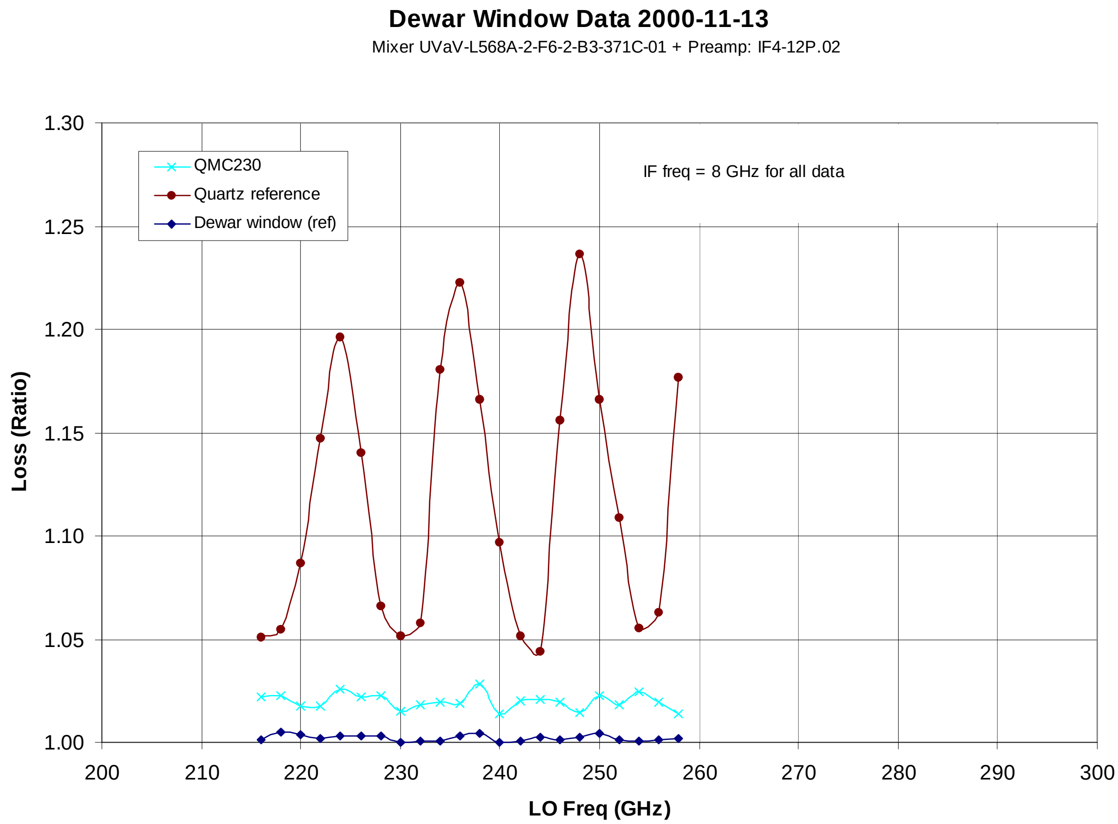


**Figure 9**. Measured losses of QMC230 and quartz reference in front of 216-300 GHz SIS receiver, tilt angle 15 degrees.

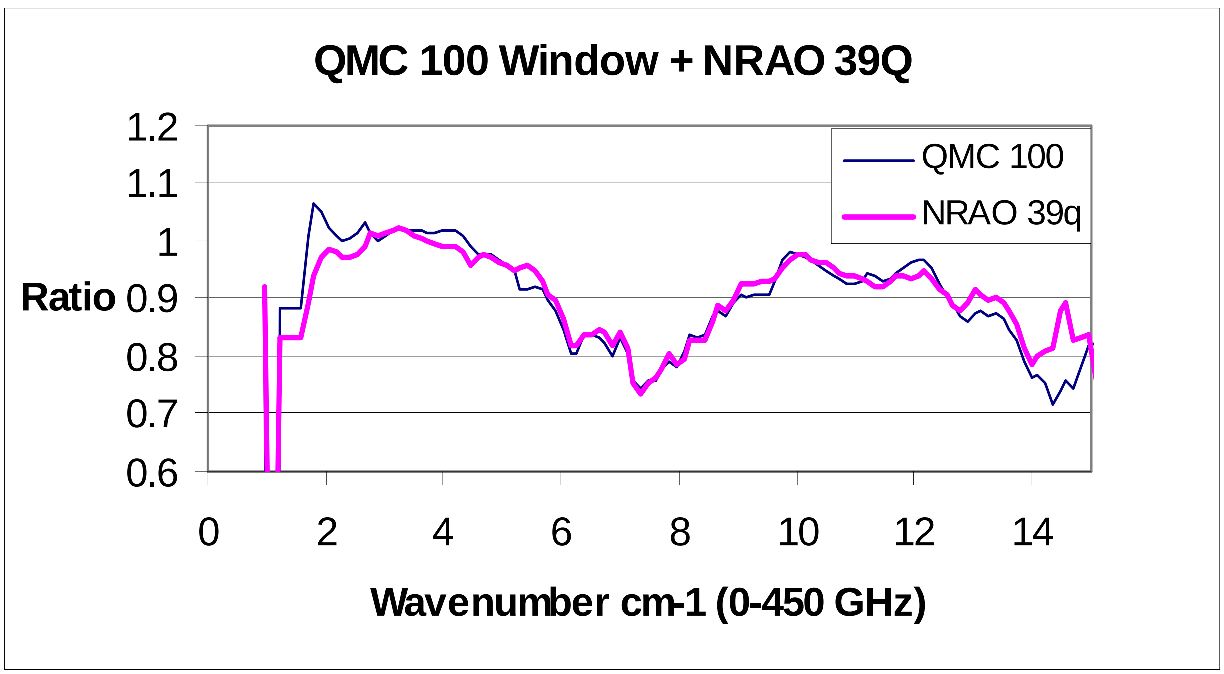


**Figure 10**. FTS measurements of windows QMC100 and NRAO 39q (ALMA band 3).

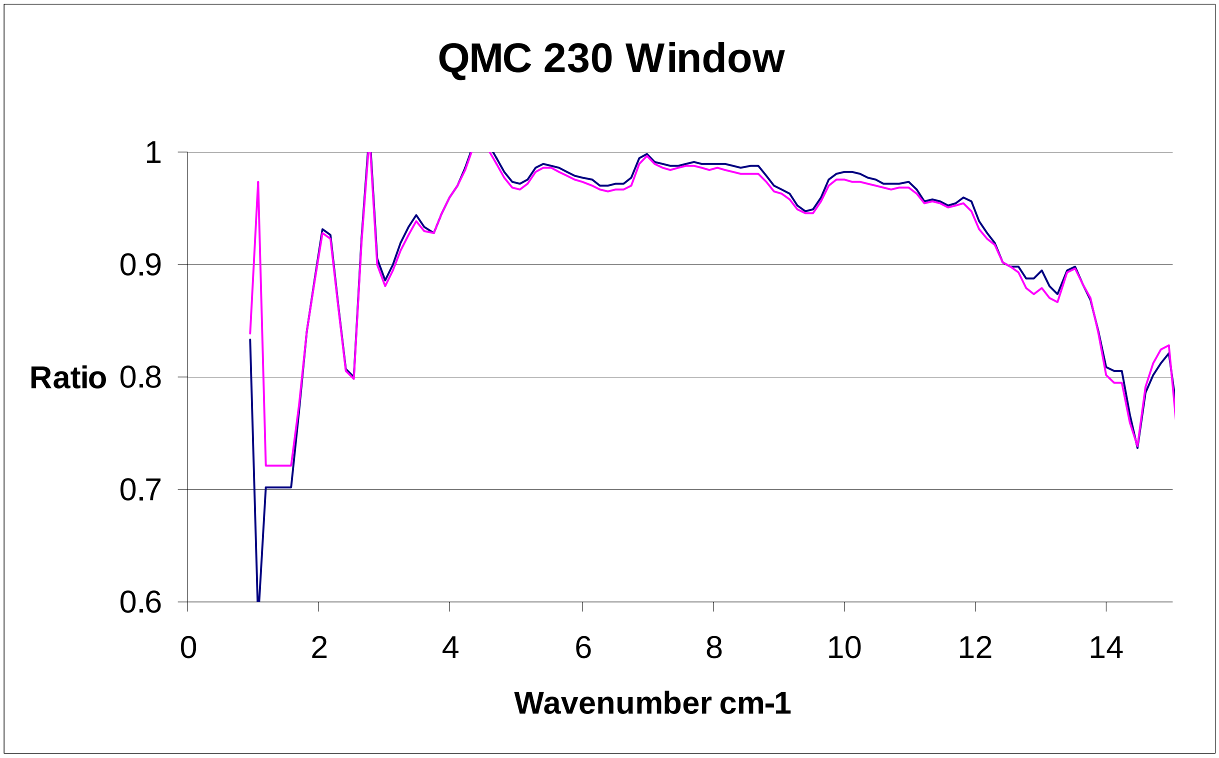


**Figure 11**. Two successive FTS measurements of window QMC230 (ALMA band 6).