Memorandum

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cc: J. Webber

From: J. Effland, R. Groves

Date: 21 June 2001

Subject: Measurement of WR-10 Waveguide Windows

1. Summary

Quartz windows have been fabricated in WR-10 waveguide by Dan Koller for use in the LO path of the JT-1 Dewar. This memo describes the equipment setup and presents insertion loss measurements from 200 to 300 GHz for these windows, which operate in overmoded waveguide. Three different measurement techniques suggest that one of the windows may have an insertion loss of 2 dB near 225 GHz, but that the loss at other frequencies is generally too small to measure with the simple setup described in this memo.

2. Test Setup

Figure 1 shows the equipment setup used for the measurement. To minimize insertion loss, the windows are designed for the same overmoded waveguide size (WR-10) as the Dewar's LO waveguide. The measurement setup used single-mode WR-4 couplers to provide good fundamental-mode matching to the LO tripler, the spectrum analyzer mixer, and the window. The latter was sandwiched between a cascade of WR-4 to WR-10 tapers that were included when reference power was measured without the windows.

Power level differences were measured with the spectrum analyzer operating as a narrow band receiver because it offers acceptable measurement accuracy when measuring the relatively small insertion losses of the waveguide windows. Although power meters provide lower measurement uncertainty, their wide-band power heads can cause significant measurement errors originating from tripler harmonics, so they were not used for the loss measurement.

Three power measurements from the spectrum analyzer were recorded directly into a spreadsheet: The power received without the window but including the WR-4 to WR-10 tapers, with the window, and then repeated again without the window. The insertion loss was calculated as the average of the first and last power readings minus the reading with the waveguide window.

3. Results

The insertion loss measured with the setup diagrammed in Figure 1 for the two fabricated windows is shown in Figure 2. The WR-4 coupler-based waveguide setup was validated by measuring 7.62 cm (3") and 15.24 cm (6") sections of straight WR-10 waveguide that were inserted as the device under test, then repeated with both sections in cascade. The results, shown in Figure 3, include a line showing the algebraic sum of the individual 7.62-cm and 15.24-cm insertion loss measurements. If the measurement was perfect, that line should match the measured 22.86-cm (9") cascade data, but it is apparent that significant measurement errors are present at certain frequencies.

Another check of the setup using the WR-4 tapers consisted of measuring the insertion loss with and without a 7.62-cm waveguide section in cascade with the waveguide window. This approach changes the resonant frequency of trapped modes, because the waveguide cavity length increases by 7.62 cm. The frequency range of interest is the high insertion loss region between 220 GHz and 230 GHz. As shown in Figure 4, there is no significant difference in the data measured with and without the 7.62-cm waveguide section.

Concerns about contamination of the window by slivers of gold from plating that may have flaked off while inserting the window into the test fixture were unfounded. Window #1 was carefully cleaned and its insertion loss measured again between 228 GHz and 230 GHz was the same as that prior to cleaning.

Two other waveguide configurations were used initially to measure the insertion loss. First, the windows were sandwiched between waveguide tapers with no couplers after the tripler. That is, following the tripler were several tapers to reach the WR-10 waveguide size of the window and another set of tapers reduced the waveguide size to WR-5 for the spectrum analyzer mixer. That configuration generally produces a poor impedance match at the tripler output that can degrade tripler performance resulting in large amplitude variations with frequency and spurious signals output from the tripler.

Attempts to validate the simple taper-based waveguide setup provided surprisingly consistent results. The insertion loss of a 7.62-cm section of WR-10 waveguide was measured in place of the window. This was repeated for a 15.24-cm section and then for both the 7.62 cm and 15.24 cm sections in cascade. Table 1 gives the results, which show that the cascade was equal to the sum of the individual measurements.

Table 1 : Setup (Waveguide Tapers Only) Validation using Straight W/G Sections

Waveguide Length	**Measured Insertion Loss**	
	227 GHz	**245 GHz**
7.62 cm (3")	1.0 dB	1.0 dB
15.24 cm (6")	3.0 dB	2.5 dB
7.62 cm cascaded with 15.24 cm	4.0 dB	3.5 dB

The second preliminary setup consisted of essentially the same configuration as shown in Figure 1, but WR-10 couplers were used and the waveguide tapers were located between the tripler and coupler and a second set before the spectrum analyzer mixer. With this configuration the couplers operate in overmoded waveguide which causes wide variations in coupling value and also has the same potential problems with poor tripler match as the initial taper-only configuration. Indeed, rapid signal level variations were observed across the 200 to 260 GHz band using this configuration. In some cases, high insertion loss spikes caused the signal level to be too low to measure with the spectrum analyzer.

Dispite the shortcomings of the initial setups, it is useful to compare results from all three measurement configurations, as shown in Figure 5. All three measurement approaches suggest that window suffers from large insertion losses near 225 GHz, but its loss at other frequencies is generally too small to measure with the setups described in this memo.

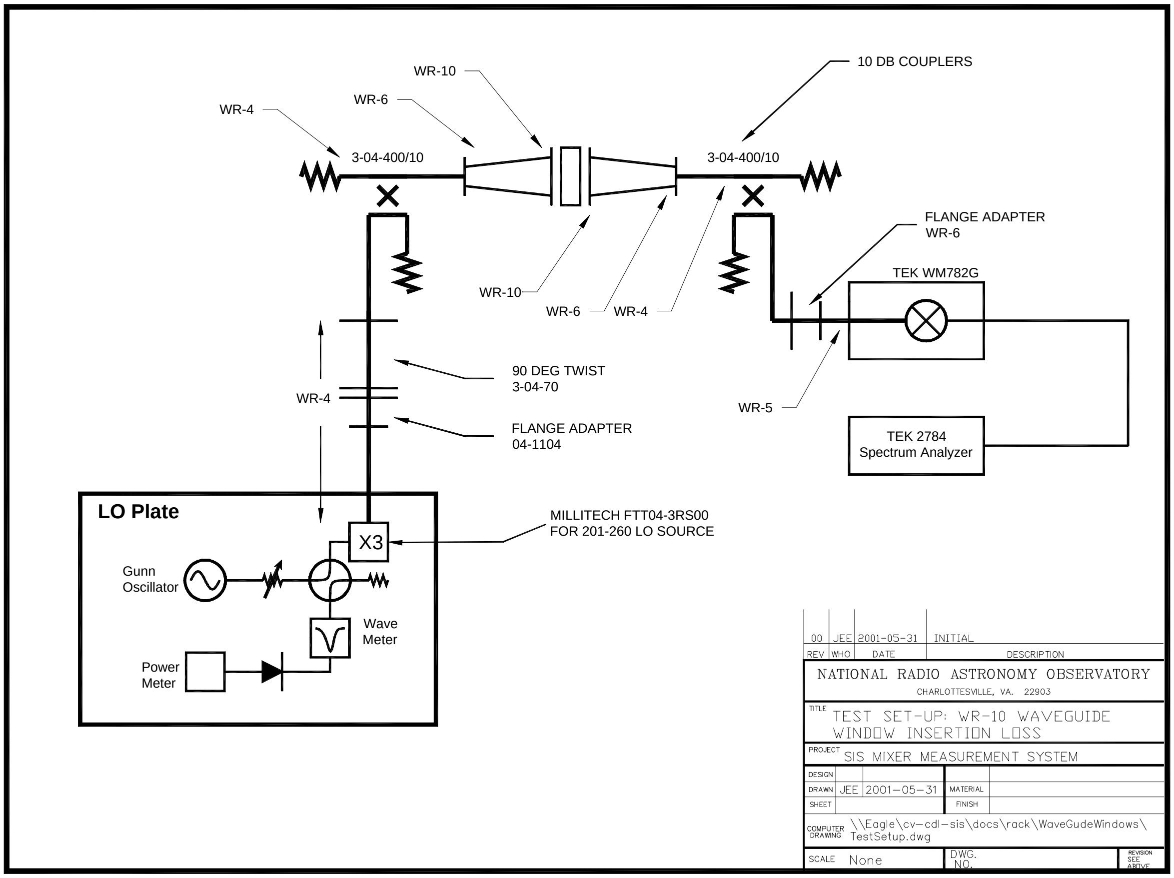

Figure 1: Test Set-Up

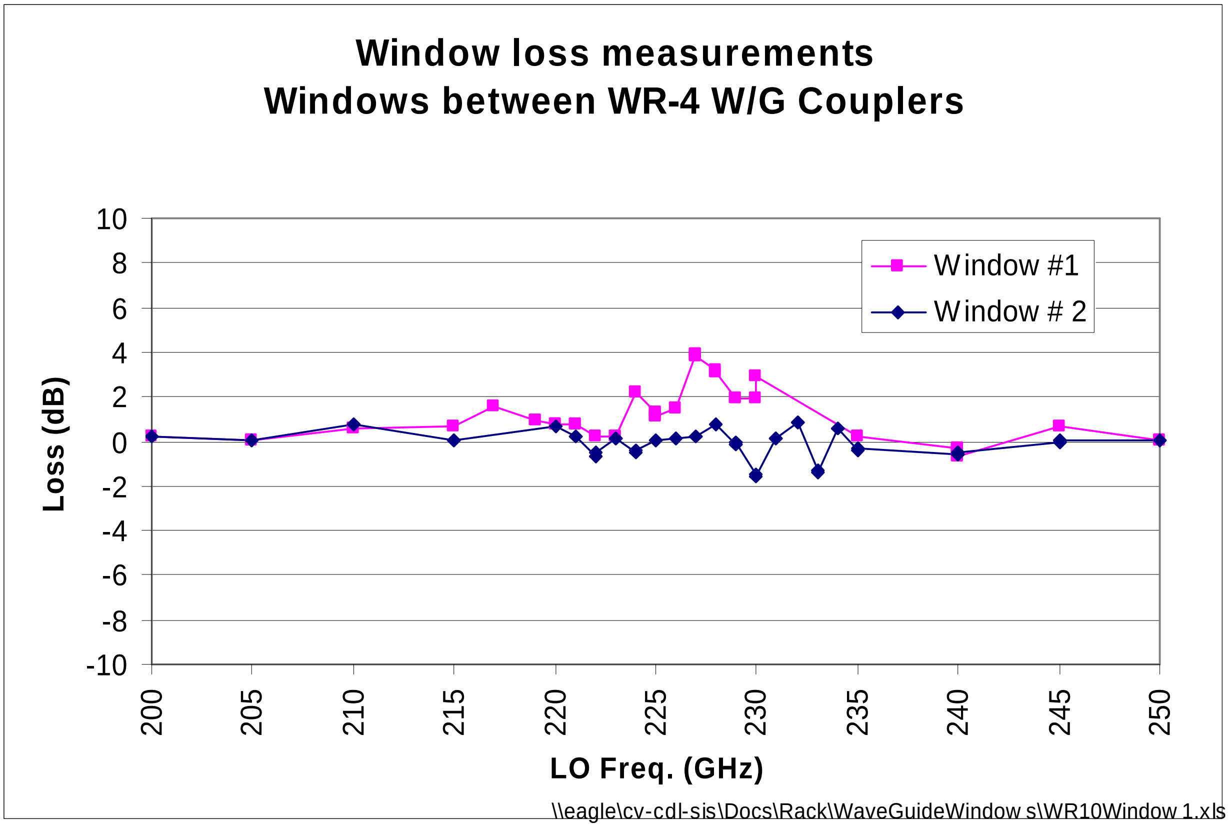

Figure 2: Measured Results

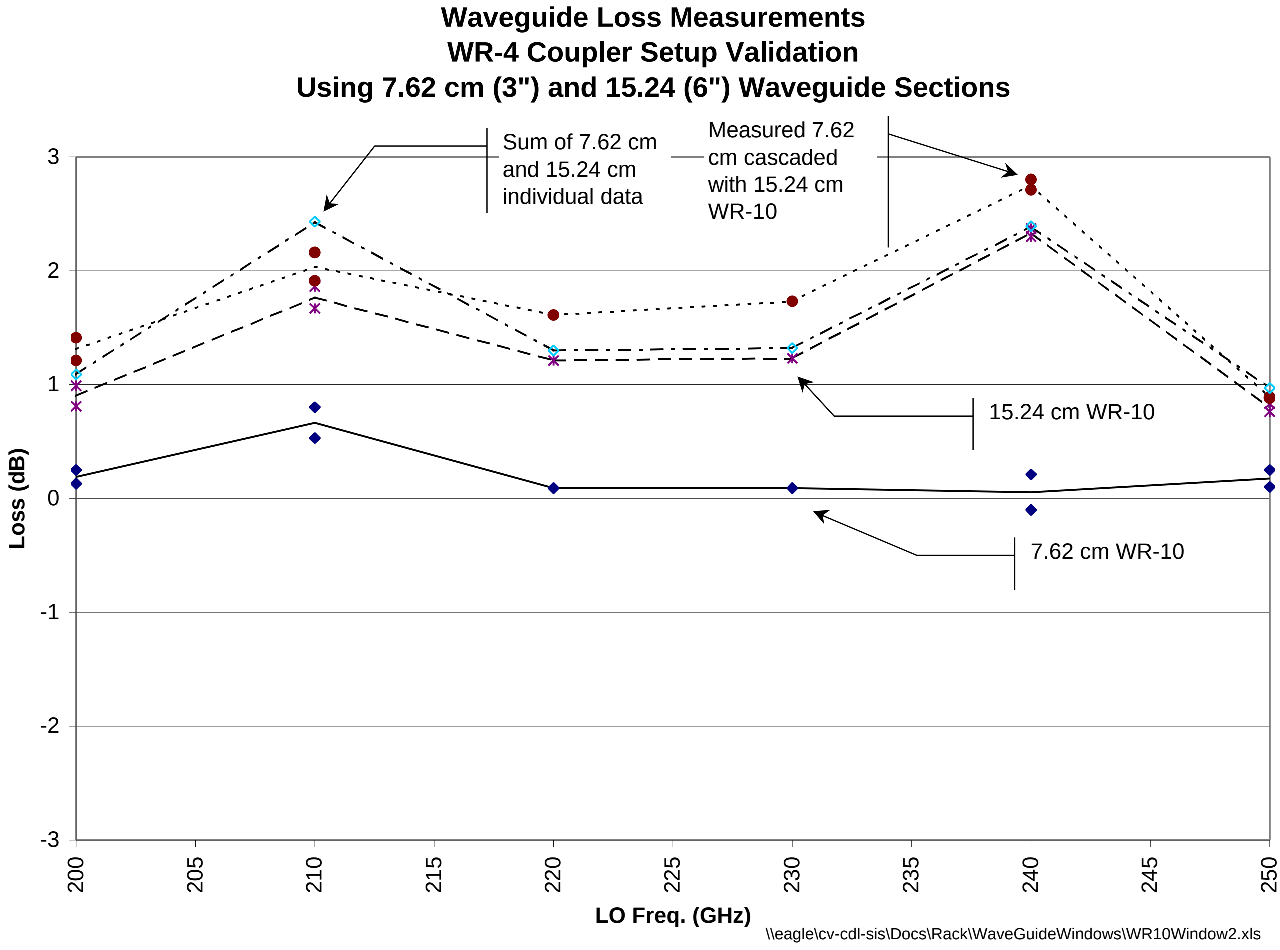

Figure 3: Validation of Setup with WR-4 Couplers

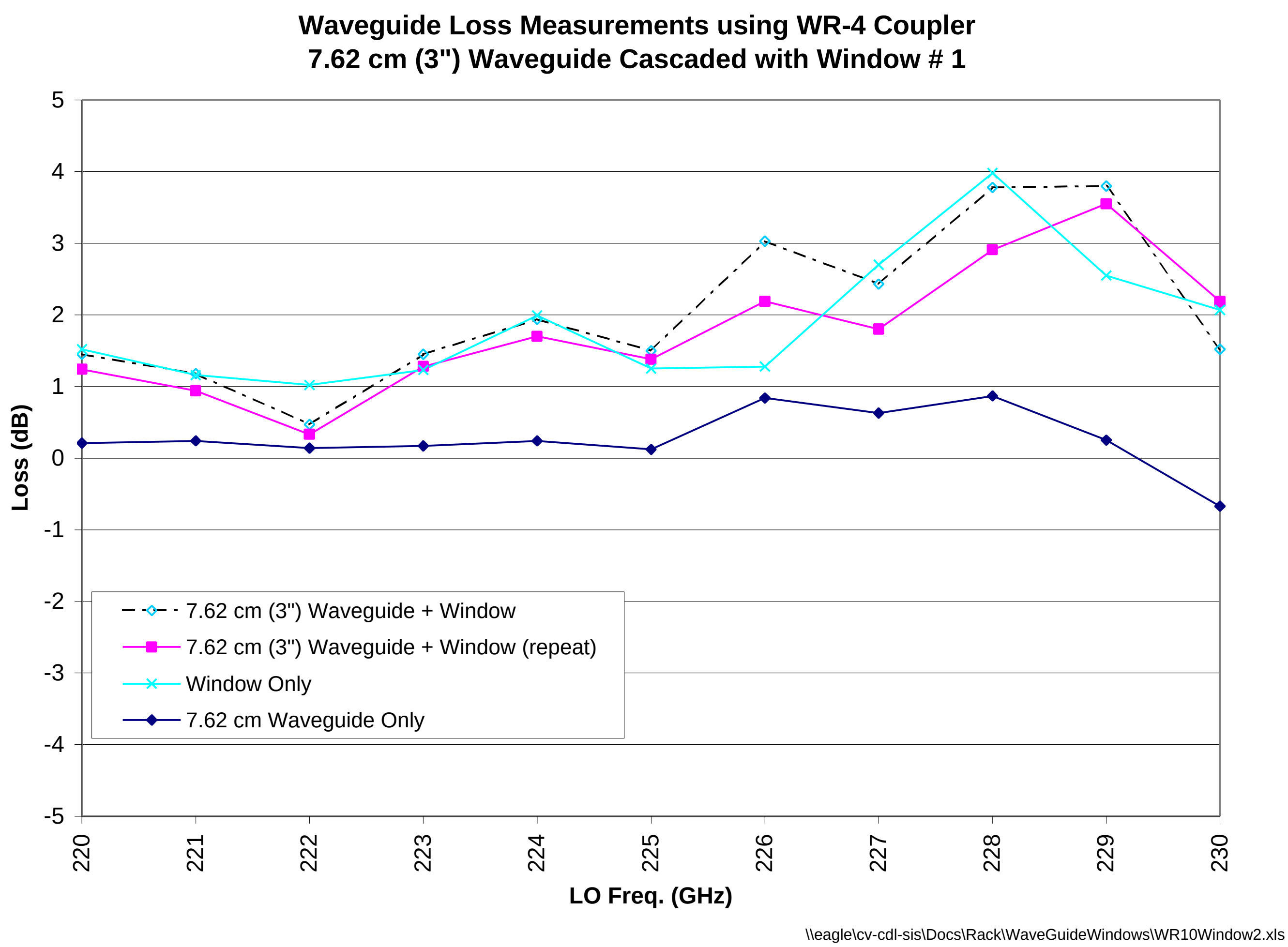

Figure 4: Window Cascaded with 7.62 cm Waveguide

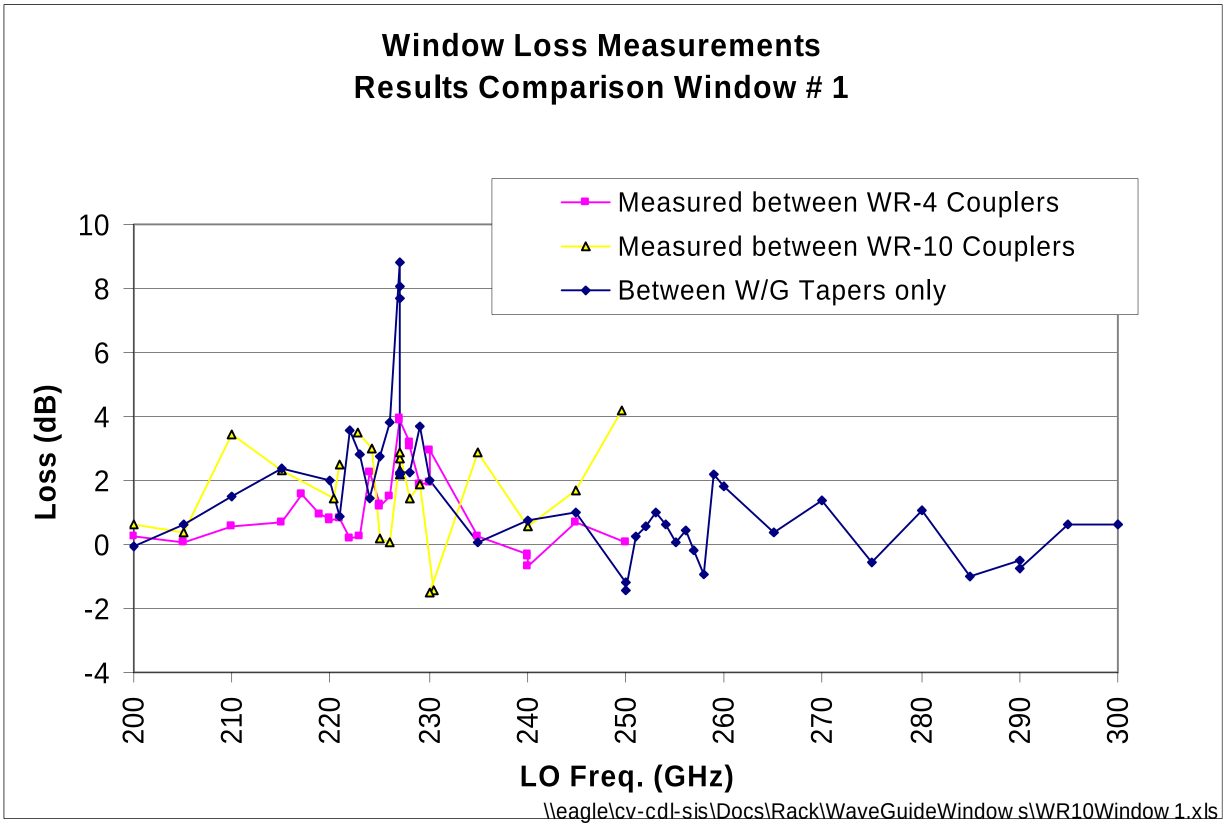

Figure 5: Comparison of Results for Different Setups