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MM-VLBI MEMO #010

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To: Millimeter-wave VLBI Group

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Subject: Standing waves from radome and subreflector at 3*mm*

Subreflector

Without a spoiler or vertex plate on the subreflector the reflected signal path loss L is approximately

$$L = \left[\frac{Af}{Ad}\right] = -60 \; dB \quad at \quad 3mm$$

where Af = effective feed aperture
Ad = effective antenna aperture

This reflection will produce a ripple with peak-peak amplitude

$$2\,T_{rad}\,L^{1/2} = 0.1K \quad (for\ T_{rad} = 50K)$$

where T_{rad} is the radiated or reflected noise.

Radome panels

The signal path loss from a flat radome panel is approximately

$$L = \Gamma G_T^2 A_f^2 / \left(4 d^2 \lambda^2\right) = -60\,dB$$

where A_f = effective area of feed = $650mm^2$
d = distance to panel = $17m$
G_T = gain of feed on panel = G_{Taper} = $-10\ dB$
Γ = panel reflectivity = 0.3 at 86 GHz
λ = wavelength = $3mm$

At 86 GHz the feed taper is actually more like -4 *dB* making the average path loss to radome panels more like -48 *dB* to any panel whose normal is oriented within about 5 degrees to the line to the feed.

Observed baseline ripple

86 GHz

At 86 GHz the standing waves are quite evident in the spectrometer baselines taken with 160 MHz bandwidth. Both the 9 MHz (period to radome) and 12.5 MHz (period to subreflector) and beats between them are present. However the picture is complex with the following characteristics:

1] Baseline ripple changes with antenna motion $\approx$ about 5 degrees is required to make the largest change.

2] Baseline ripple changes with subreflector focus motion - but not quite in the expected manner. The behavior is like double sideband system that is, subreflector changes after the magnitude of the 12 MHz ripple component but does not move the ripple phase in frequency. 0.25λ motion will dramatically change the ripple amplitude. Baselines taken $0.5\,\lambda$ apart look similar.

3] Making a L.O. change does not move the baseline ripple in the expected manner.

4] Typical ripple magnitude is from about 0.1 to 0.5K peak-to-peak.

115 GHz

At 115 GHz the effect of the radome is barely evident and the 12.5 MHz period ripple dominates and has the expected characteristics for single sideband system. The observed characteristics are as follows:

1] Baseline ripple changes very little with antenna position.

2] Ripple phase reverses with $0.5\,\lambda$ change in subreflector focus.

3] Ripple phase changes by 90°with 0.124λ change in subreflector focus - but amplitudes also change. i.e., behaves as SSB system with poor image rejection.

4] Typical magnitude is 1K in beam switching mode with $T_s \approx$ 700K.

5] The magnitude is reduced when the circular polarizer is in place.

6] Ripple amplitude increases with increased sky noise, spill-over and atmospheric noise.

7] Ripple character changes with subreflector azimuth tilt.

The mechanism which explains the observed characteristics is one in which incoming noise is reflected from the SIS mixer back to the subreflector and back again into the mixer to correlate with the previously received noise. The circular polarizer helps because it reduces the reflection from the subreflector which reverses the sense of circular. The apparent loss of image rejection evident at 86 GHz and to a lesser degree at 115 GHz is probably the result of a higher reflection coefficient for the mixer in the image band. Some of the complexity of the ripple pattern is the result of additive back-end noise which contains a complex pattern. This adds or subtracts in the difference spectrum depending on the sign of the imbalance in the front-end noise. Another contribution to the ripple may be ripple in the HEMPT noise which appears in the difference spectrum owing to a modulation of the SIS mixer gain. Some $\approx$9 MHz periodicity in frequency switched spectra is apparent even when the feed is covered with an absorbing load. Further investigation has shown that this most likely is due to multiple reflections involved in a circuitous path in the dewar.

Since the ripple magnitude and character changes with small subreflector tilt the reflections are more complex then those expected from a perfect hyperbola. It is likely that subreflector surface irregularities and poor alignment of the central 4" plug are responsible for the complex nature of the reflections.

Proposed fixes

1] Spoil subreflector reflection

A vertex plate was proposed to spoil the subreflector reflections. Unfortunately the vertex plate only spoils the reflection for the main beam and has insufficient coverage in the focal plane to spoil the reflection for the comparison beam which is displaced by 12". A spoiler cone can do better in this respect - see figure 1. Because of the difficulty of aligning a vertex plate or small cone, a large cone (7" diameter) or absorber should be considered. Tests with an absorber show that the subreflector reflections can be dramatically reduced.

2] Arrange for quarter wave path difference between main and reference beams

Additional rejection of subreflector reflections could be obtained by adjusting the offset mirror to give a quarter wave path difference at the observing frequency. At 115 GHz a motion of no more than 20 mils is required. Once set, the bandwidth for reasonably good cancellation would be about 120 MHz.

3] Use of circular polarization

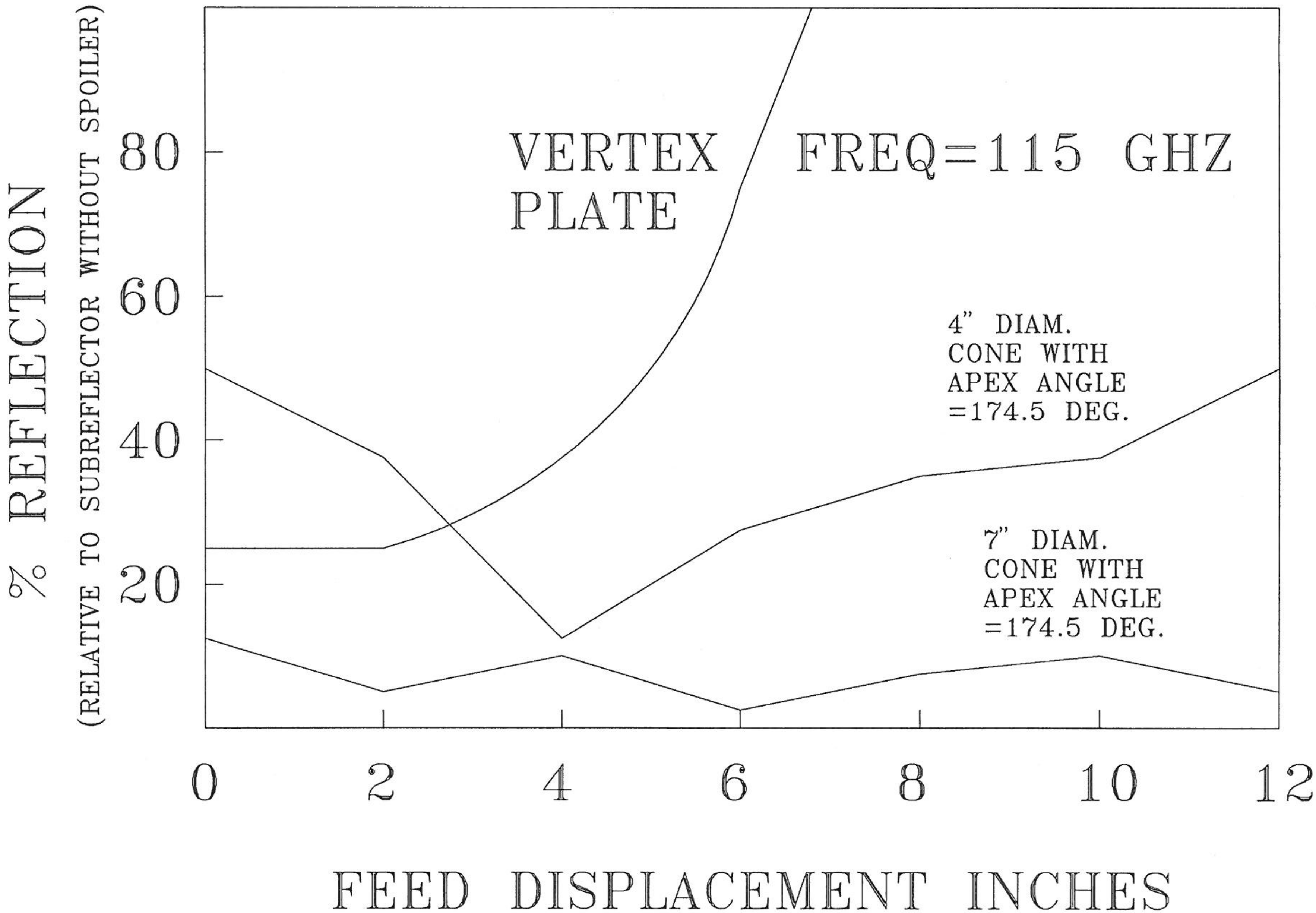
A circular polarizer can be used to provide additional rejection of radome and subreflector reflections. The 86 GHz VLBI polarizer improves the baselines at 115 GHz.

4] Reduction of modulated reflections from beam switcher

Changes in the reflection from the switching wheel and its associated parts produce a difference in SIS mixer characteristics between the signal and reference beams leading to baseline ripple with period of about 200 MHz. Some small pieces of absorber placed on the inner rim of the wheel might reduce this problem. Ideally, the beam switcher should be as symmetrical as possible.

5] Reduction of reflections inside the dewar

Consideration should be given to placing some absorber material inside the dewar to quench any circuitous paths of internal reflection around the walls of the dewar and inner shield. If at all possible, some baseline ripple tests should be done on the ground with feed covered with absorber.



% REFLECTION
(RELATIVE TO SUBREFLECTOR WITHOUT SPOILER)
80
60
40
20
VERTEX
PLATE
FREQ=115 GHZ
4" DIAM.
CONE WITH
APEX ANGLE
=174.5 DEG.
7" DIAM.
CONE WITH
APEX ANGLE
=174.5 DEG.
0
2
4
6
8
10
12
FEED DISPLACEMENT INCHES

Fig 1