Measurements of the prototype dual-load calibration system on BIMA

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Goal To measure, as a function of frequency, the coupling of the calibration loads at the secondary to the beam.

Experimental setup Ambient and cold (liquid nitrogen) loads in polystyrene boxes were alternately placed in front of the vertex, with the antenna at the zenith. The boxes were mounted on a track, allowing computer control with drive times of 10–20 seconds. The weather varied from light to heavy cloud cover. Measurements of the coupling coefficient were derived from 20-second integrations on each load and two 30-second measurements of the synchronous difference signal from the subreflector. These integration times were sufficient to make thermal contributions to the overall uncertainties small. With drive times, it took about 4 minutes to make one complete measurement; secular instrumental drifts on shorter timescales could introduce errors.

The ambient load was 0.74 m $\times$ 0.74 m, easily large enough to intercept the entire beam. Its temperature was measured with several thermistors to within about 0.1 K.

The cold load was 0.69 m $\times$ 0.43 m.[1] We placed the load with the smaller dimension along the driven axis, and (before adding nitrogen) measured total power as a function of box position. The additional total power from ambient compared with the sky allowed us to select a load position at which the load completely intercepted the beam; the box was just adequate in size. To prevent a standing wave between the feed and the liquid nitrogen due to reflections at the nitrogen/box interface, the box was tilted by 5 degrees compared with the feed. The feed was thus weakly coupled (less than 1%) to ambient within the cabin. A correction has been applied for this effect.

The difference signal was provided by the hardware previously described (ASP Conf. Ser. 17, p 309). All measurements were made at 1 mm. For linearity we used the six-junction NRAO mixer on antenna 6.

Results The coupling coefficient at 1 mm is shown as a function of frequency in the following figure. The uncertainty was estimated from repeated measurements at one frequency (221 GHz).

[1] We had previously planned to use a larger load, in a box with a base corrugated to ensure Brewster's angle at the nitrogen/polystyrene interface. However, the several boxes obtained have all leaked nitrogen. Having eliminated the easier possibilities, we understand the only feasible method to be custom injection molding, expected to cost about $15k.

With retuning between measurements at this frequency the standard deviation (SD) was 2.7% (8 measurements); the error bars on the figure represent this number. However, the measurements with retuning were interrupted prematurely by rain. There are also still some unexplained glitches attributed to the data acquisition electronics. These have partially been filtered out, but continue to affect the results at the 2% level. Further, one point was particularly discrepant. A longer series of measurements made earlier without retuning had SD of 1.7% (20 measurements). We will work more on the electronics and repeated measurements with retuning at the next opportunity.

Also on the figure are measurements from a previous run using the old loads.

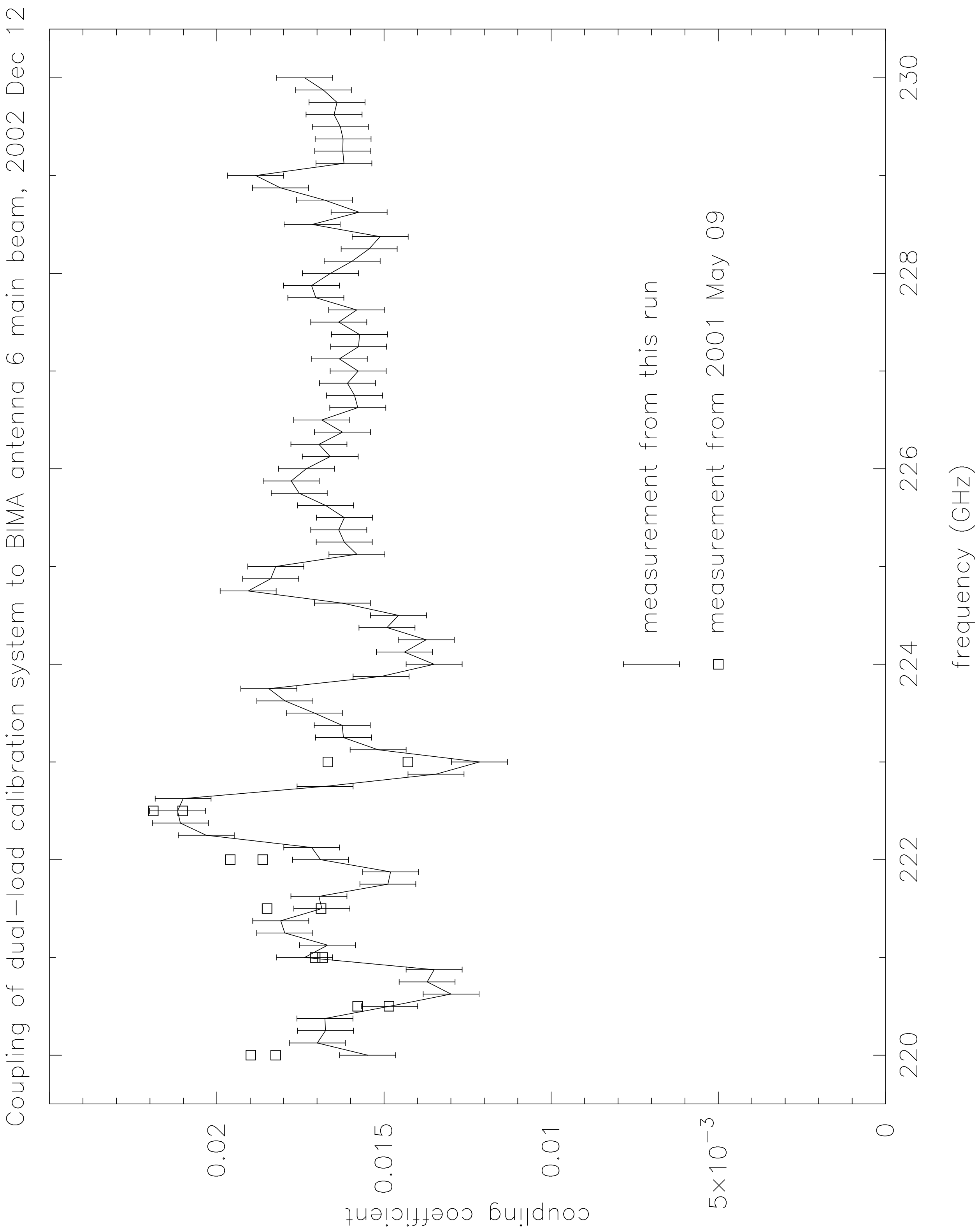
Discussion This experimental setup has allowed us for the first time efficiently to make measurements of the dual-load calibration system. Over timescales of about a day, the reproducibility is of order the error bars shown on the plot. The measurements of 2001 May 9 were made with inferior, smaller loads that were difficult to maneuver into place and probably did not completely intercept the beam. Yet the frequency structure revealed by these new measurements is also apparent in the older measurements. The fact that the earlier results are generally higher could be due to the partial interception of the beam. But the overall conclusion is that the coupling coefficient, including its basic frequency structure, has not varied substantially over time.

However, the frequency structure itself is not yet understood. There is an apparent periodicity at about 1 GHz (corresponding to 15 cm), within a lower-frequency envelope. The optical path contains several discontinuities of dimension about 15cm: within and adjacent to the feed, and at the subreflector. Note that a Gaussian beam analysis including the effects of truncation at the dewar window (Dick Plambeck) predicts a smoothly varying coupling coefficient of 0.020–0.021 over the range 220–230 GHz.

Our plan is to make a further series of measurements within the next several weeks. Subject to the availability of test time on the array, we will:

- repeat measurements to check reliability over time, and the effect of retuning
- make measurements with reduced hardware near the beam (polarization plates, calibration wheel, WVR reflector, etc)
- extend the frequency range
- measure in the 3mm band.

Of particular interest is the cause of the frequency structure. Input and suggestions are welcome.


Coupling of dual–load calibration system to BIMA antenna 6 main beam, 2002 Dec 12
coupling coefficient
0
5×10⁻³
0.01
0.015
0.02
frequency (GHz)
220
222
224
226
228
230
measurement from this run
measurement from 2001 May 09