NATIONAL RADIO ASTRONOMY OBSERVATORY

Green Bank, West Virginia

October 21, 2002

MEMORANDUM

To: Janet Stewart, Patrick Newton

From: Michael Stennes

Subject: Cryogenic testing of Millitech isolator, model FBI-12-RSESN

CC: Roger Norrod

The attached report describes the recent S-parameter measurements of the Millitech isolator, model FBI-12-RSESN, at room temperature, and at cryogenic temperatures. This isolator is the first unit built using an epoxy (recommended by NRAO) having a fast set-up time and thought to be suitable for use at cryogenic temperatures. The report describes the measurement techniques, and presents the results of the following sequence of measurement sets:

- Room temperature S-parameters, taken in April 2002 when the unit was first received by NRAO.
- Cryogenic measurements at T = 17 Kelvins (October 9, 2002).
- After allowing the isolator to come to room temperature, it was again cooled to 17 Kelvins and tested cold on October 11, 2002.
- A final set of S-parameters was taken (twice) at room temperature.

The significant results of these tests are as follows:

- The isolator has survived two cool-downs, although there is some change in S21 noted when comparing the April and October data sets (at room temperature).
- The isolator meets the insertion loss specification at both room-temperature, and at cryogenic temperature (17 Kelvins). There is some degradation in isolation (S12), but performance is still reasonable.

S-Parameters Measured at Room-Temperature, April 2002

The following plots summarize the measured data, taken at room temperature. To illustrate the change in S21, the first graph compares data taken before and after cooling the isolator.

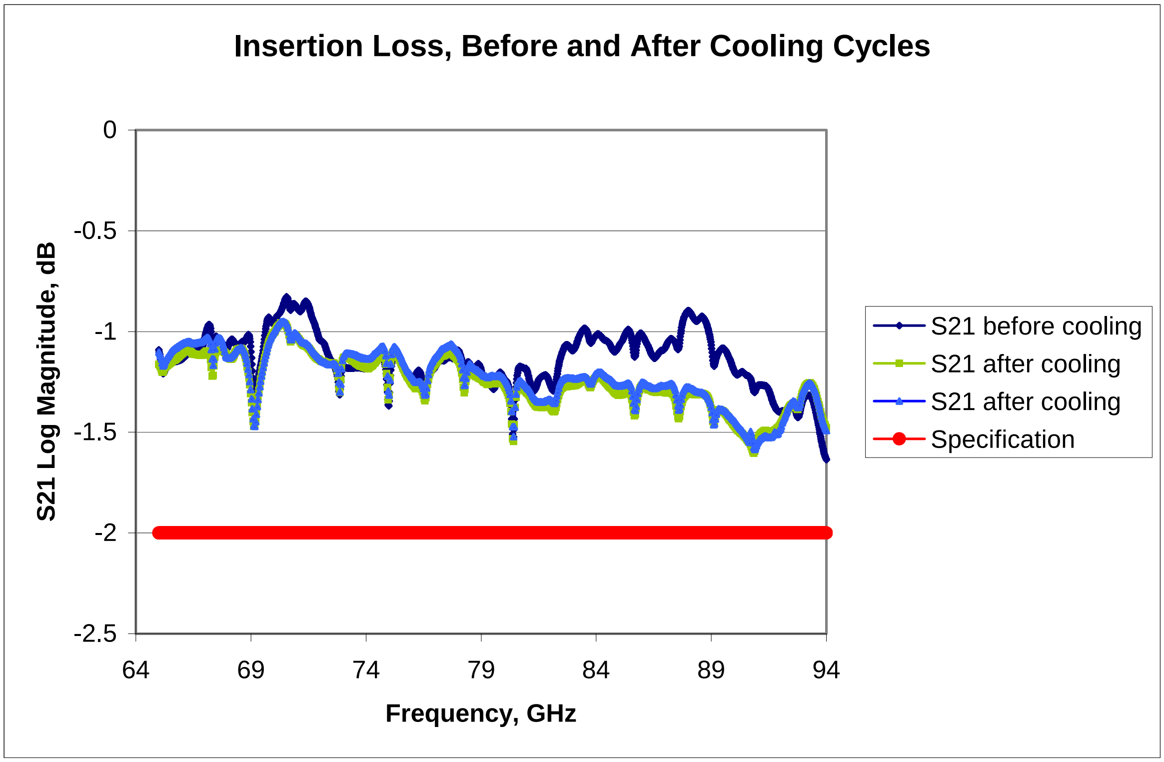

Figure 1. A comparison of S21 before and after cooling cycles.

Resonances seen in the data (figure 1) are of some concern. The frequency range of measurement was narrowed, with a finer frequency resolution so that a closer inspection could be made. The graph of figure 2 shows a zoom view of one of these resonances. We see that the resonance is not very deep, in fact, the insertion loss is still within the specification of 2.0 dB. However, the resonances are still a concern to us as they may be an area (frequency range) in which our receiver (of which the Millitiech isolator will be a part) may be sensitive to environmental fluctuations (temperature, mechanical vibrations, etc.).

Also note that there was some change in S21, possibly the result of cooling the unit to cryogenic temperatures. Additional cooling cycles will be performed later, and from subsequent measurements we will determine if S21 will continue to change.

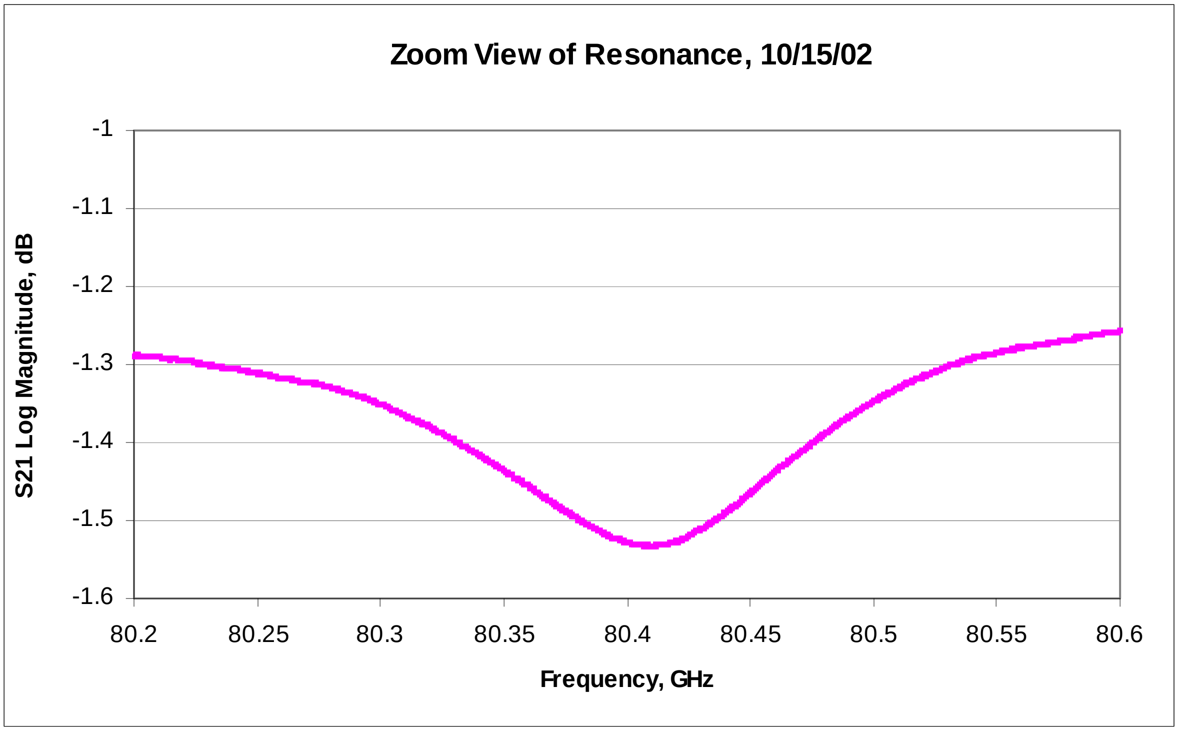

Figure 2. A closer look at the resonance at 80.4 GHz.

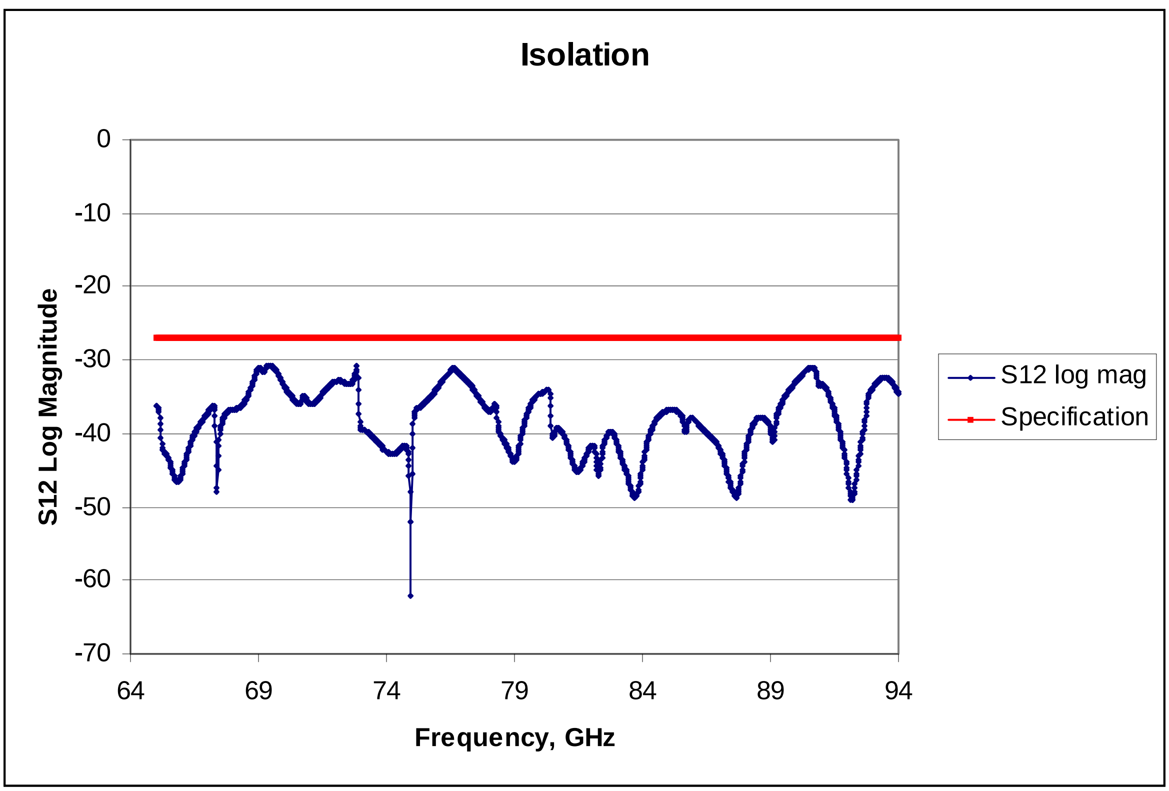

Figure 3. Isolation, measured at room temperature.

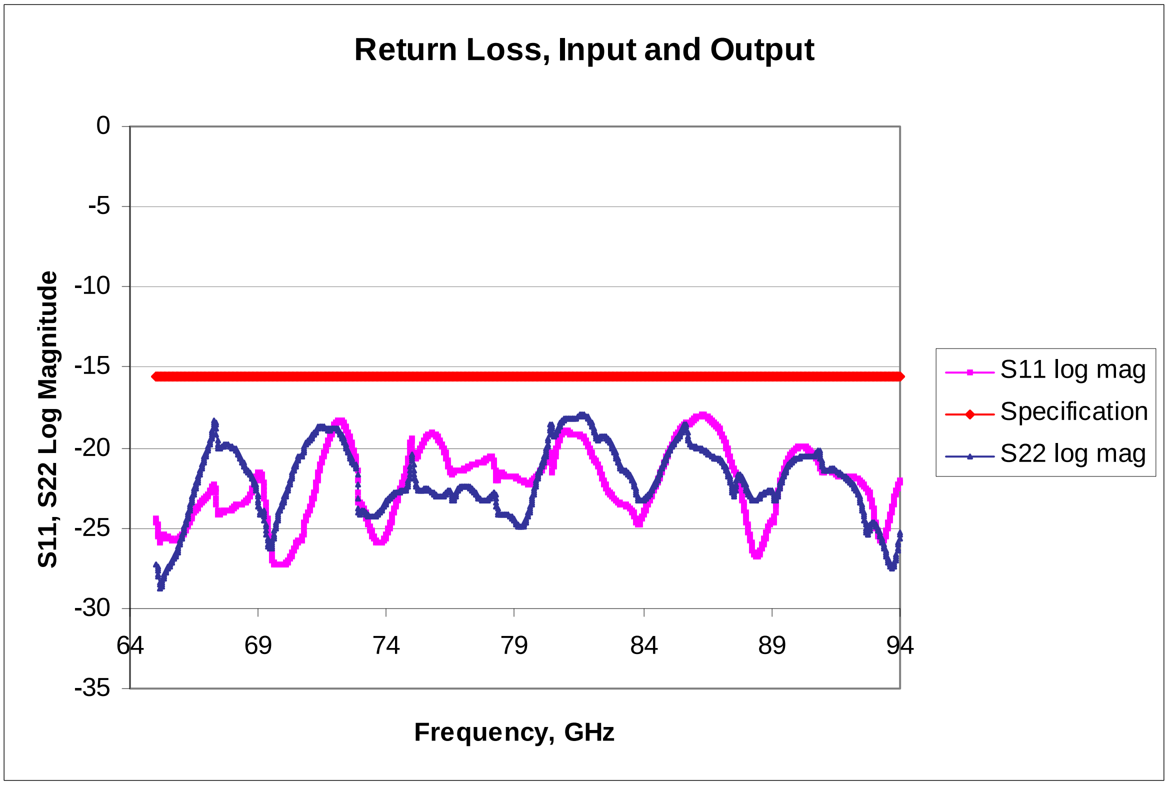

Figure 4. Input and output return loss, measured at room temperature.

Cryogenic Measurements, October 2002

The isolator was cooled to 17 K using a closed-cycle helium refrigerator, attached to a dewar as shown below in figure 5. Ideally, one would like to calibrate the network analyzer at points A and B, to take out the effects of the various waveguides and vacuum windows. However, because it takes several hours to cool the contents of the dewar, such a calibration would become invalid due to drifts in the instrumentation.

Alternatively, we chose to calibrate the network analyzer at reference planes located outside of the dewar (see figure 5). Using this scheme, the isolator (DUT) parameters can be de-embedded using S11 data taken with waveguide shorts located at points A and B. This method yields good results when care is taken to keep all reflections below –25 dB or so.

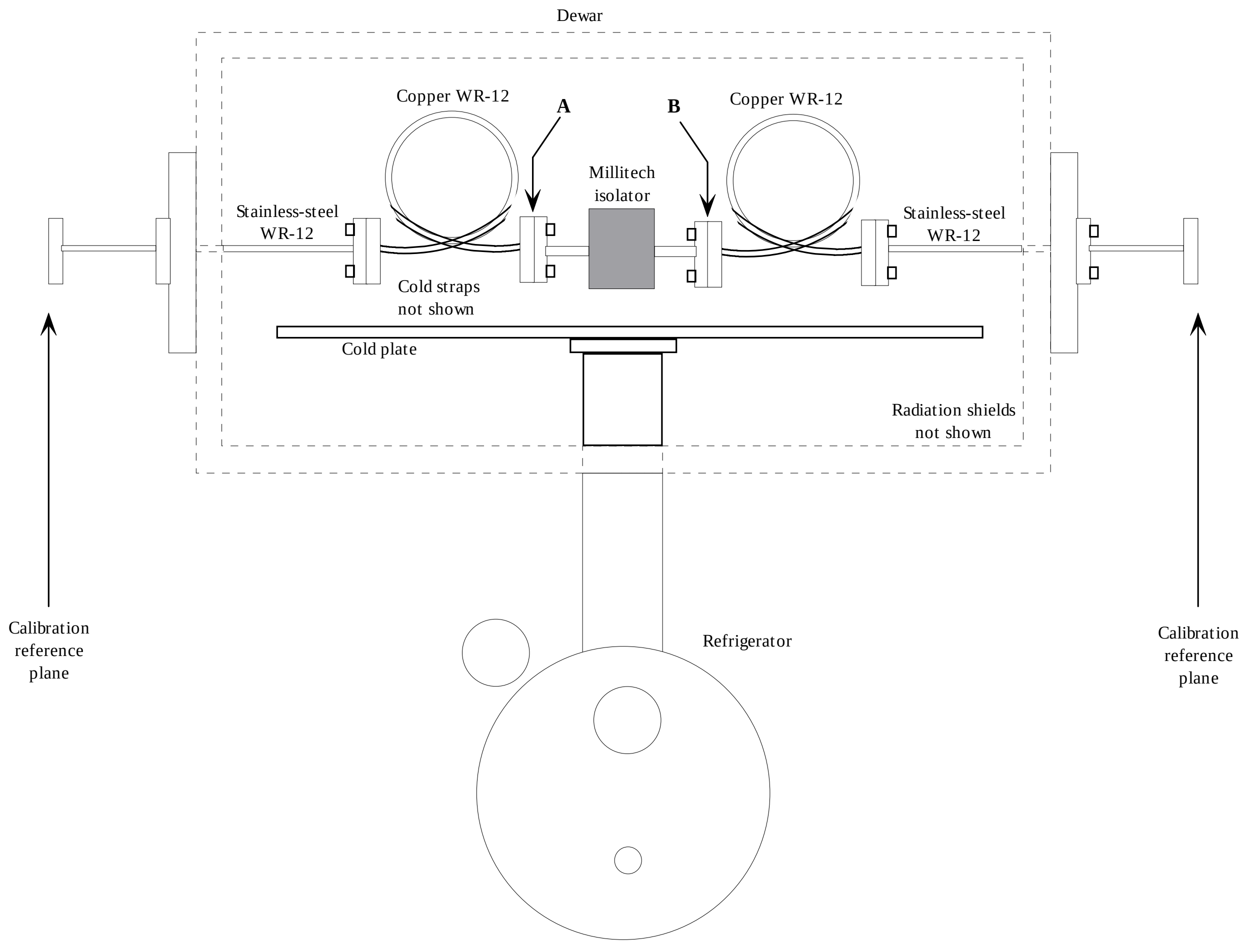

Figure 5. An illustration of the equipment needed to perform cryogenic testing.

Test Procedure and Data Reduction:

- Place waveguide shorts at flanges A and B, cool the dewar to 17K.
- Calibrate VNA, measure and record S11 on ports 1 and 2.
- Warm the dewar, remove shorts and install isolator (DUT).
- Measure and record S21 and S12.
- Subtract half of S11 and half of S22 from each of the DUT data sets (S21 and S12).

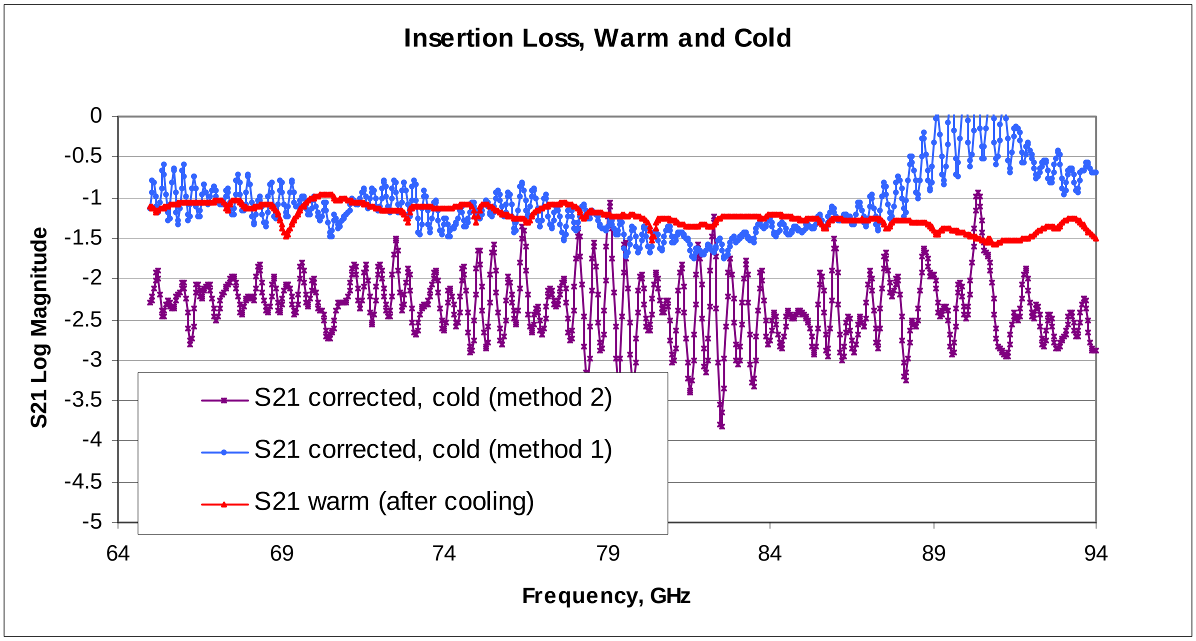

Figure 6. Insertion loss measured cold (using two methods), compared to S21 at room temp.

The additional waveguides used in method 2 introduced large ripple in the data. Method 1 yielded good results, except for frequencies above 89 GHz where large reflections in the test waveguides corrupted the DUT data.

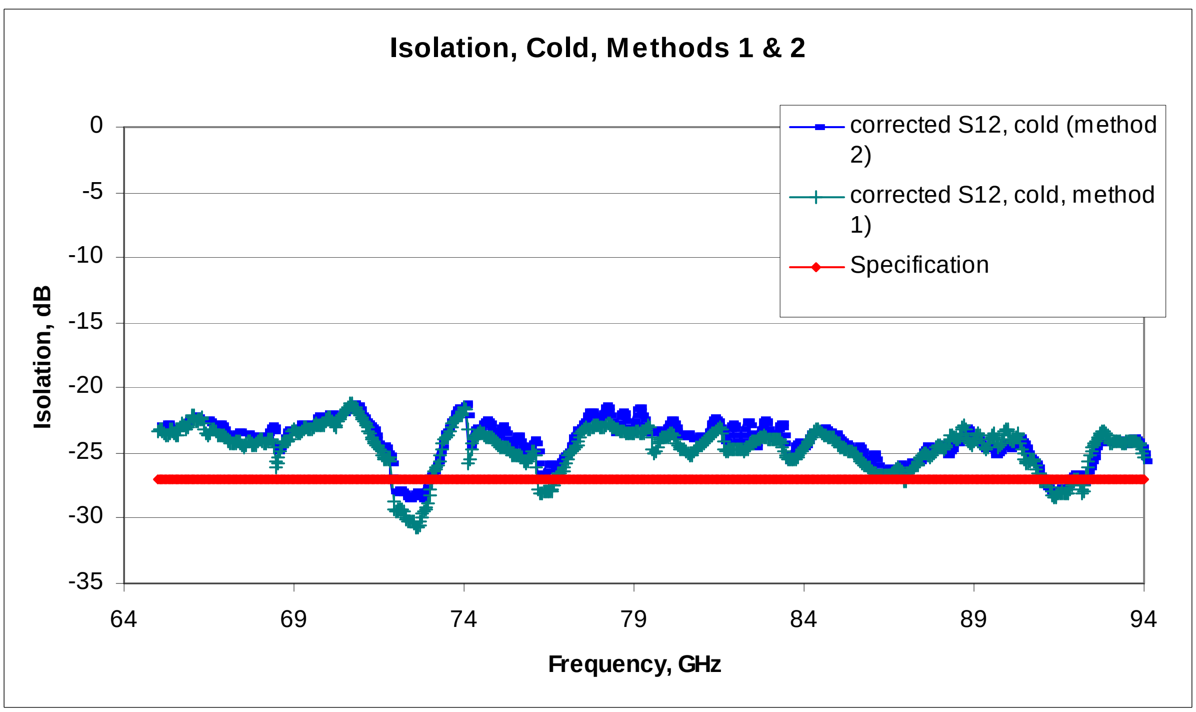

Figure 7. Isolation (S12) measured cold, using two methods.

Conclusions

In general, the measurement results look quite good. Our primary concern at this time is the existence of resonances which are easily seen in the warm S21 data and the cold S12 data. It is our hope that Millitech can modify the design in such a way as to reduce or eliminate them.

It is evident that the new epoxy did survive two cool-down cycles, however we did see some change in S21 log magnitude when comparing the pre- and post-cooling data. We plan to perform more cooling cycles with a set of measurements being performed after each, to see if the S-parameters are continuing to change.