

On Wednesday, August 10, 2016, Carla Beaudet performed RFI tests on the SNAP FPGA board, housed in a chassis provided by Rich Lacasse, the assembly henceforth referred to as the EUT, (Equipment Under Test). The EUT used a Tenma 72-2010 linear DC bench PS to supply 12 VDC, and a HP8654A signal generator to supply 250 MHz at +2dBm as the reference. No other lines or ports were connected. The EUT is intended for installation as part of the HERA project, at a distance of 5m from the focal point of the nearest HERA antenna, which will be used as the reference distance for the purposes of this evaluation.

For testing purposes, the EUT was simply powered on. At power-up, a flash memory loads a stored personality to the FPGA which should be performing functions representative of its intended use; this was not verified. The 15-pin connector that was filtered in the third test condition had only the 2 wires for the DC power connected to it. The following conditions were tested:

- “Box Open”
- “Box Closed”, no filter on 15-pin Dsub connector
- “Filtered”, i.e. box closed and seams taped, 4000pF PI filter on 15-pin Dsub

The EUT was tested in the anechoic chamber at a distance of 7m from the receive antenna over the range 70 MHz to 1 GHz using the EM-6950 log periodic antenna, and from 1 GHz to 6 GHz and also 10 GHz to 12 GHz (requested test ranges) using the EM-6961 Horn Antenna. With the box open, strong broadband emissions were seen between 70 MHz and ~570 MHz as well as strong narrowband emissions at harmonics of the clock frequency (which also show up in the Test Bed scans, and is simply coaxial leakage) and one weak narrowband emission at 10.3125 GHz, which showed up somewhat intermittently, and is suspected to be coming from the 10Gbit Ethernet port which has a bit rate of 10.3125 Gb/s. Calibrated measurements were performed on worst-case signals from the wideband spectral plots using a span of 10 MHz and a long (100 sweep) average. The resolution bandwidth used for all measurements was 10 kHz. Spectral plots of the emissions follow summaries of the calibrated worst-case measurements:

Worst Case Emissions Summary, Box Open							
Frequency (MHz)	Long Average Measurement (dBm)	Power Density @ GBT Reference Point (dBW/m2/Hz)	ITU-R RA.769 Continuum Limit (dBW/m2/Hz)	Emission Exceeds Continuum Limit by (dB)	ITU-R RA.769 Line Limit (dBW/m2/Hz)	Emission Exceeds Line Limit by (dB)	Emission Exceeds FCC Class B Limit <sup>4</sup> by (dBm, EIRP)
74.83	-46.90	-159.38	-258.01	98.63	-245.15	85.77	NA
144.34	-40.33	-152.90	-258.91	106.01	-244.84	91.94	NA
151.19	-39.52	-152.86	-259.00	106.13	-244.80	91.94	NA
167.83	-37.07	-151.19	-258.91	107.71	-244.73	93.54	NA
171.36	-38.73	-152.81	-258.89	106.07	-244.71	91.90	NA
174.69	-38.25	-152.40	-258.87	106.47	-244.70	92.30	NA
181.54	-39.46	-153.72	-258.83	105.10	-244.67	90.94	NA
190.35	-42.81	-157.09	-258.78	101.69	-244.62	87.54	NA
193.29	-42.29	-156.45	-258.76	102.31	-244.61	88.16	NA
198.18	-43.17	-157.83	-258.73	100.90	-244.59	86.75	NA
250.00	-23.59	-137.31	-258.43	121.13	-244.35	107.05	6.90
262.80	-50.50	-163.91	-258.36	94.45	-244.29	80.38	-19.71
368.53	-55.34	-165.63	-256.43	90.80	-243.81	78.18	-21.43
2249.87	-75.16	-163.69	-248.73	85.04	-235.71	72.02	-27.44
10312.50	-77.50	-147.60	-240.06	92.46	-224.89	77.29	-11.35
Worst Case Emissions Summary, Box Closed							
Frequency (MHz)	Long Average Measurement (dBm)	Power Density @ GBT Reference Point (dBW/m2/Hz)	ITU-R RA.769 Continuum Limit (dBW/m2/Hz)	Emission Exceeds Continuum Limit by (dB)	ITU-R RA.769 Line Limit (dBW/m2/Hz)	Emission Exceeds Line Limit by (dB)	Emission Exceeds FCC Class B Limit <sup>4</sup> by (dBm, EIRP)
50.73	-50.98	-164.83	-253.69	88.86	-245.26	80.44	NA
63.26	-40.07	-153.05	-256.03	102.99	-245.21	92.16	NA
74.83	-69.66	-182.14	-258.01	75.87	-245.15	63.01	NA
179.58	-61.99	-176.29	-258.84	82.54	-244.67	68.38	NA
250.29	-25.47	-139.18	-258.43	119.25	-244.35	105.17	5.03
302.94	-60.61	-171.75	-258.13	86.38	-244.11	72.36	-27.54
315.66	-71.29	-182.75	-258.06	75.31	-244.05	61.31	-38.54
500.57	-51.74	-158.95	-254.09	95.13	-243.21	84.25	-14.75
748.39	-64.53	-166.78	-253.34	86.57	-242.07	75.30	-22.57
10312.52	-77.33	-147.43	-240.06	92.63	-224.89	77.46	-11.18

**Figure 1: Worst-Case Emissions**

\*FCC Class B compliance not estimated<sup>4</sup> below 200 MHz due to lack of antenna calibration and chamber reflectivity

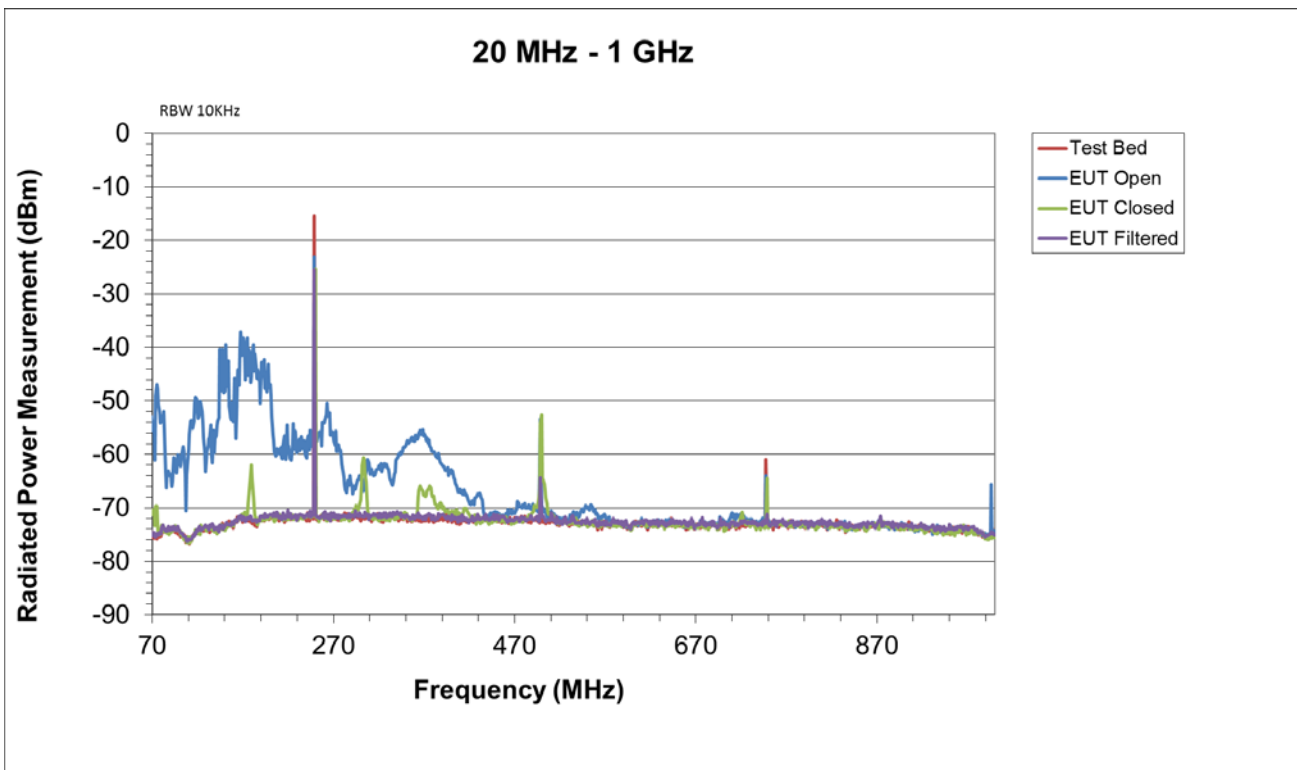


Figure 2: 20 MHz – 1 GHz

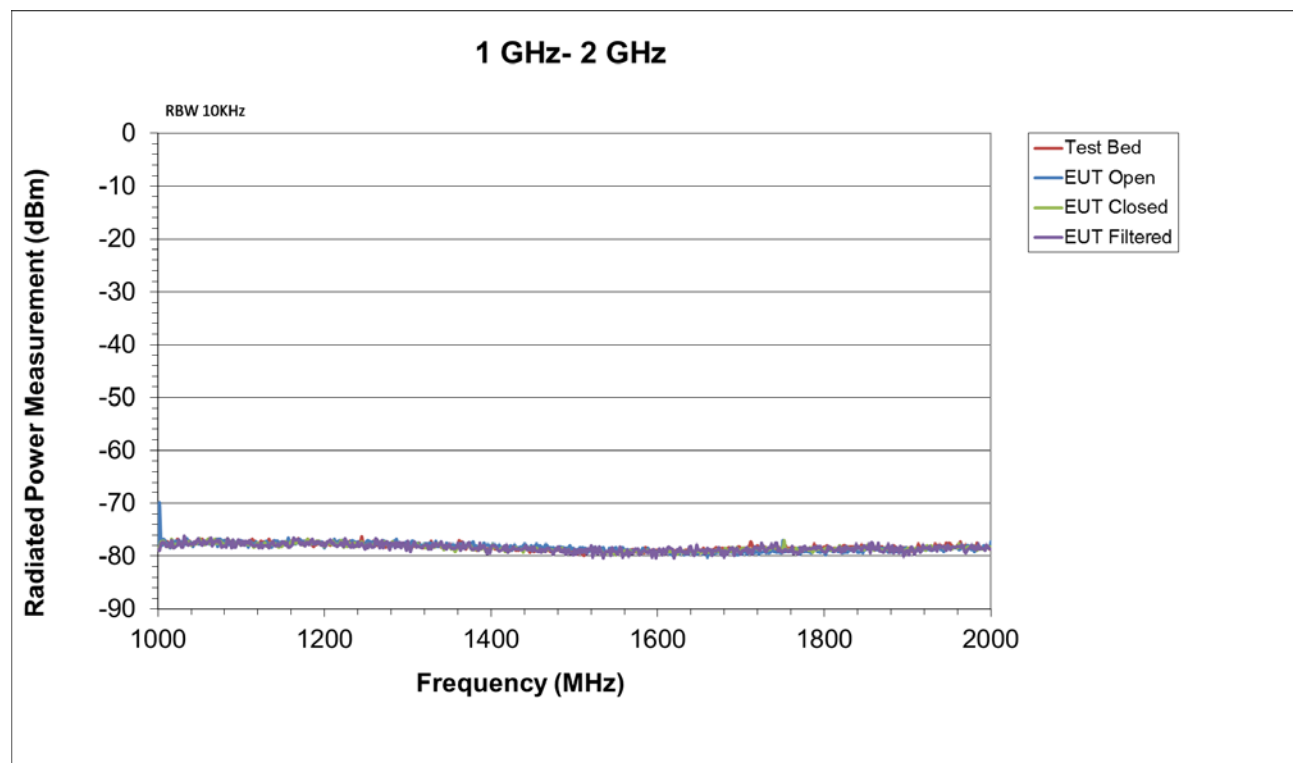


Figure 3: 1 GHz – 2 GHz

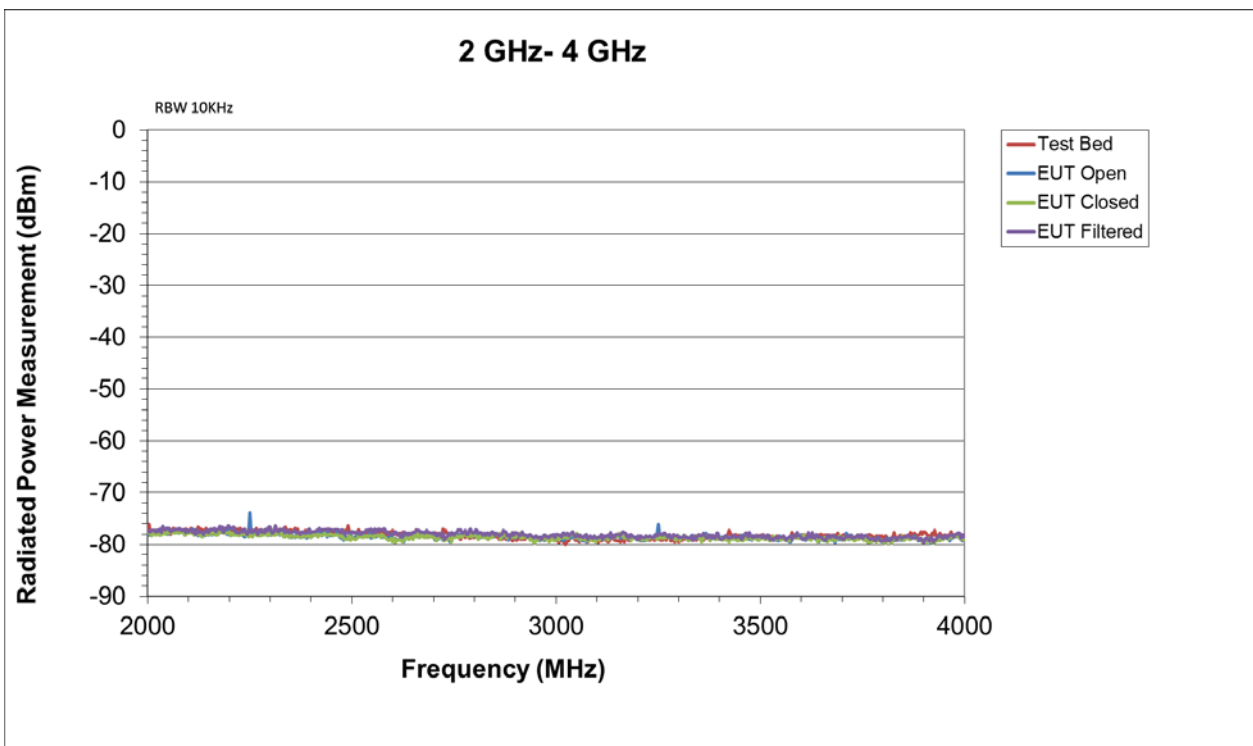


Figure 4: 2 GHz – 4 GHz

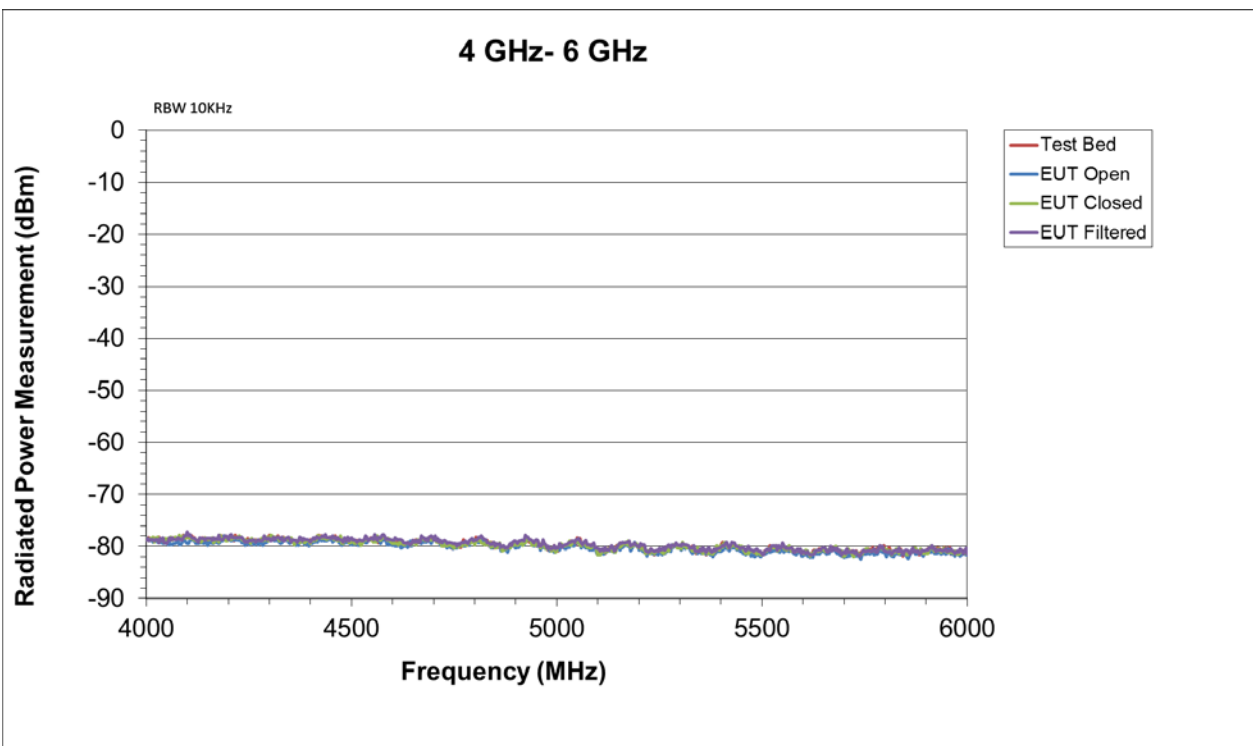


Figure 5: 4 GHz – 6 GHz

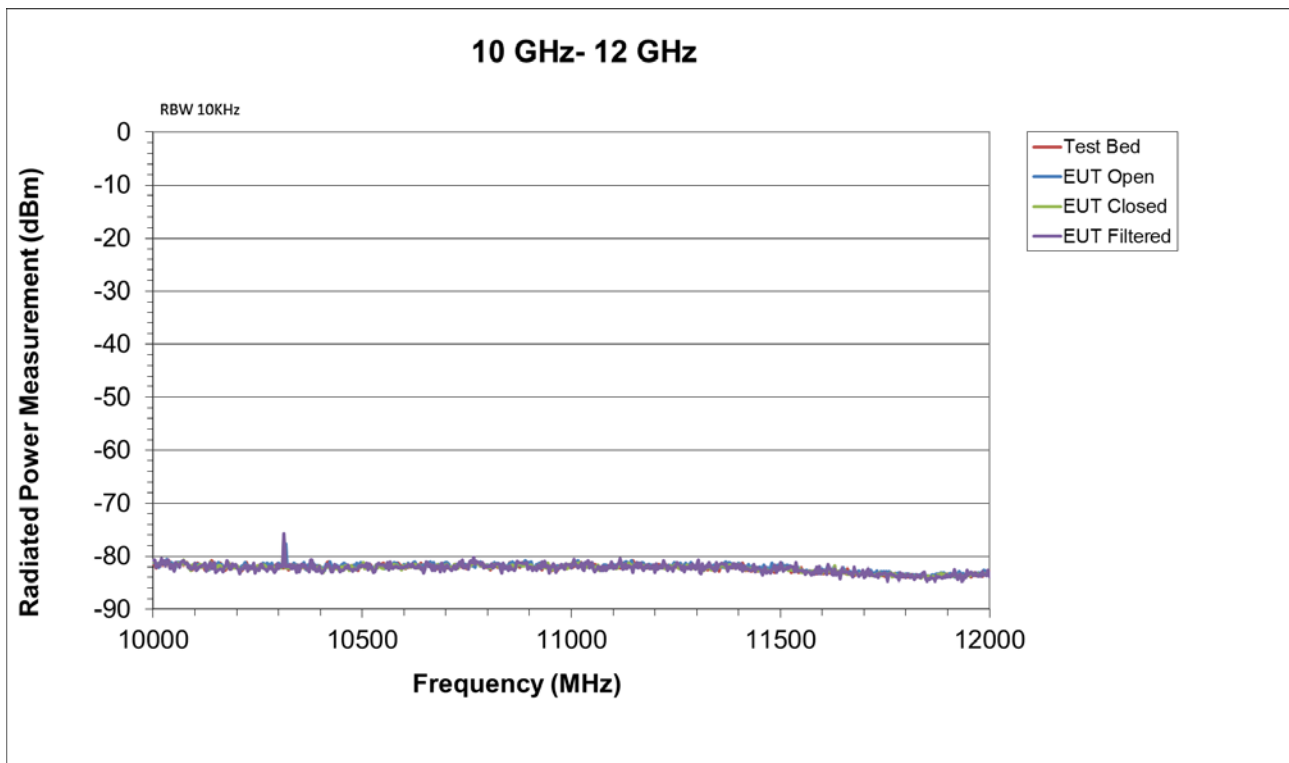


Figure 6: 10 GHz – 12 GHz

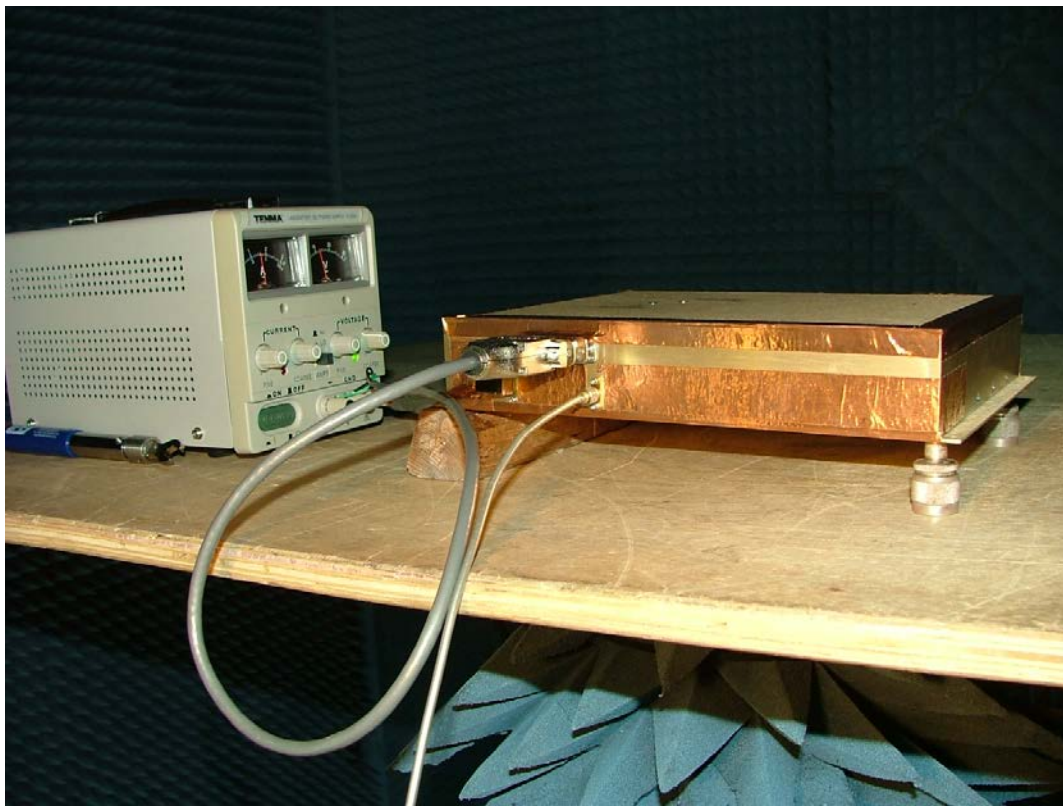


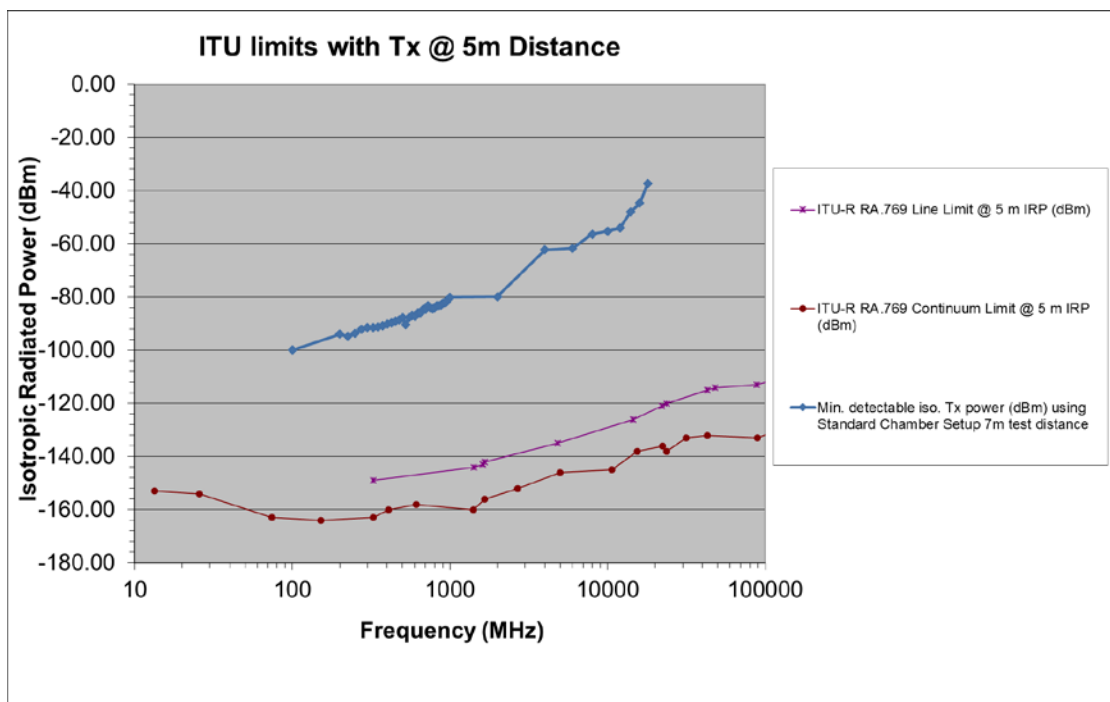
Figure 7: EUT photo, showing copper tape and filter

Worst-case signals are evaluated according to the limits and methodology set forth in J. R. Fisher's 1997 paper titled "RFI Radiation Limits in The Vicinity of GBT". These limits are consistent with the ITU-R RA.769 limits, which are used worldwide as a basis for protecting Radio Astronomy instruments from harmful RFI. In summary, the EUT is recommended for installation at a 5m distance from the HERA receivers only if:

1. the chassis seams are taped with copper tape
2. the 15-pin D connector is replaced by a 15-pin array of 4000pF PI filters\*, and
3. the HERA astronomers are willing to tolerate likely interference at harmonics of the clock frequency.

\*The API PN for the 15-pin male D-sub array of 4000pF PI filters with solder-cup connections is 56-711-015.

The chart below illustrates the practical limitations of our RFI measurement setup when evaluating equipment intended for installation so close to the reference point. Roughly speaking, for a 5m reference distance, there is a 60dB sensitivity gap between chamber sensitivity and the ITU-R RA.769 continuum limit.



**Figure 3: Limitations of Chamber Setup**

Note #1: No allowance was made for shielding from incidental structure.

Note #2: RFI limits to radio astronomy are found J. R. Fisher's report "RFI Radiation Limits in the Vicinity of the GBT" dated May 9, 1997.

Note #3: Methods & calculations used for RFI tests are established by J. R. Fisher's report of August 1994, "Evaluation of Electrical Device Interference Potential to Radio Astronomy Observations."

Note #4: FCC Class B compliance is estimated, not assessed, since we do not use the requisite quasi-peak detector in our measurements, we do not use a turntable, and we have a somewhat reflective chamber at frequencies below 2 GHz, and use an antenna for which calibration is extrapolated at frequencies below 200 MHz.