Modified Orbital LNB1075S-500X-WN60 LNB RF Emissions Test Results.

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Analysis Date: 20130415
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Background:

The new (and replicated) Atmospheric Phase Interferometer (API) at Very Large Array (VLA) radio telescope site is designed to use new Orbital Research Low Noise Blocks (LNB). The new LNBs generate a 10750 MHz LO signal to convert the Ku satellite downlink band to low L-band. The LNBs were found to generate single-tone RFI at a number of microwave frequencies. In order to reduce the power of the unwanted RF emissions, one LNB was modified to use a spiral RF gasket in place of the commercial weatherproofing O-ring. A second was fitted with small pads of thin ferrite absorbing material within the LNB enclosure. Tests were made in the EVLA/ALMA shielded chamber at the VLA site in order to determine the RF emissions of the modified LNBs. Previous tests had measured the detectable RF emissions of a number of unmodified Orbital LNBs.

Test Goals:

- Measure the RF emissions of 2 modified Orbital Sciences LNBs.
- Compare the results to the EVLA detrimental thresholds at a representative distance.

Test Results Summary:

At the representative distance of 37m from an EVLA antenna, both LNBs, when open, emitted RFI from 30 to 50 dB above the EVLA detrimental limits at 5 microwave frequencies. Adding the spiral gasket and sealing-up the first LNB reduced the resulting emissions to below our detection limit at all but 1250 MHz, where the spurious signal remained 30 dB above the limit. Sealing up the ferrite-loaded LNB attenuated LNB left emissions from 20 to 35 dB above the limit at 3 of the 5 frequencies tested.

Recommendations:

The use of spiral RF gasketing should clean up the LNB enough to permit operation at the API site. The 1250 MHz frequency is already heavily “occupied” by RFI from local radars and the Russian GLONASS L2 signals, so the addition of a single CW tone at that frequency will not materially reduce VLA observing capabilities. The addition of ferrite loading does not help enough to make it worth adding to a spiral gasket filtered LNB. An external absorber and conductive shielding sleeve might help, as seen in the 2012 tests, but such a mitigation method might reduce the LNB longevity due to overheating.

Test Description:

Each LNB was placed on a fiberglass cart, 1m from the test chamber walls, at the south end of the test chamber. The LNBs were powered via a linear DC power supply located outside the chamber. A MicroCircuits ZABT-2R15G bias-T located outside the chamber south bulkhead multiplexed the DC power and a 10 MHz reference signal (at +4 dBm) through the test chamber bulkhead and onto a single coax cable within the chamber. The coax provided the DC and RF inputs to the LNB, and the low L-band RF out. A 12 GHz signal was also sourced through the south bulkhead and a microwave coax to an

ARA 8-12 GHz feedhorn. During testing, proper operation of the LNBs were verified by observation of the down converted 12 GHz test signal on an external spectrum analyzer.

The receiving antenna used was the Pomeroy, wide-band bi-conical, placed at a central, fixed position on the receiving end of the test chamber during all data collections. Either a single or 3 positions of the Johnson mode tuner were used for data collections. The following standard cables were used for the test:

15 ft, ¼ in Heliax SMA: Pomeroy receiving antenna to chamber inner bulkhead,
Times TM175mm1500KMKM: chamber outer bulkhead to spectrum analyzer input.

These are the standard cables used during the calculation of the chamber Insertion Loss data vector. In addition, the following cables were used to feed the LNB, and to source a test beacon into the chamber:

76 inch Teledyne-Storm Accutest microwave cable to feed the 12 GHz test signal to the feedhorn.
96 inch Teledyne-Storm PhaseMaster microwave cable to feed the LNB under test.

The receiver used was the HP 71210C modular spectrum analyzer system. The spectrum analyzer's wide-band, 1 – 26 GHz internal pre-amp module was set to off for all tests.

The following external pre-amps were used for the tests:

B&Z Technologies bz0218sc1-SN1130 broadband microwave LNA. A 10 dB attenuator was inserted between the Pomeroy antenna output and the LNA input to prevent saturation during digital emissions tests.

The external preamps were powered via a lab, AC to DC power supply. The AC power was from an inside-chamber, filtered AC outlet via an extension cord.

For all collections, the receiving antenna was kept fixed at "position 2" (center of the receiving area) of the chamber, while the mode tuner was set to rotate continuously. The spectrum analyzer was set to capture the peak power level while the tuner rotated.

The receiving equipment set-up for the tests was:

Band	**Freq Start (GHz)**	**Freq Stop (GHz)**	**RBW (Hz)**	**RL (dBm)**	**Int Attn (dB)**	**Int P-amp? (Y/N)**	**Pre-pre-amp attn (dB)**	**SA Mode**
1	1245	1255	10000	-40	0	N	10	Max Hold
2	2684	2694	10000	-40	0	N	10	Max Hold
3	5370	5380	10000	-40	0	N	10	Max Hold
4	8057	8067	10000	-40	0	N	10	Max Hold
5	10745	10755	10000	-40	0	N	10	Max Hold

Data Collected:

A total of 20 data points were collected:

- 5 with the spiral gasketed UUT enclosure open.

- 5 with the spiral gasketed UUT enclosure sealed.
- 5 with the ferrite loaded UUT enclosure open.
- 5 with the ferrite loaded UUT enclosure sealed.

All data and analysis files and this test report are located at or under the following directory:

\\filehost\evla\techdocs\RFI\chamber-tests\emissions-tests\API\

Data Analysis:

The 20 emissions test data values were imported into an Excel spreadsheet for analysis.

The Effective Isotropic Radiated Power (EIRP) values and EVLA detrimental threshold levels were calculated and plotted for each test set-up.

EIRP values as a function of frequency were calculated as follows:

1. The peak power value was collected for each frequency point. (Using the peak power value collected as the chamber mode tuner rotates insures an absolute worst case value of power in the reverberation chamber.) A chamber loss vs. frequency point was interpolated from the chamber Insertion Loss (IL) files located at sheet "IL" of each of the analysis spreadsheets. The IL equation had been previously created via the chamber calibration procedure detailed in the Tanner Oakes report, "Reverberation Chambers", dated 20050426, located at: \\filehost\evla\techdocs\fe\working_files\Coop\Test_instructions.

   The calibration used removes the loss of the transmission line as well as the transmit antenna return loss. The interpolation was accomplished by allowing Excel to create a polynomial fit to the calibration data and plot the equation used. The polynomial equation was formatted for maximum precision, so as to eliminate the round-off error seen in previous IL curve equations. The polynomial equation was then used with the frequency point list for that particular group of tests to create a matching IL data vector. A plot of the EVLA/ALMA reverberation chamber, IL data vector may be seen as **Figure 1**, below.
2. The peak EIRP level in the received (instrumented) bandwidths (in dBm) was calculated by subtracting the external pre-amp gain, adding-in the pre-pre-amp attenuation, subtracting the small receiving antenna loss factor of .46 dB from the peak, and subtracting the interpolated, chamber IL vector from the received, peak power vector.
3. Finally, the peak EIRP level in dBW was calculated from the dBm value by subtracting 30 dB for the dBm to dBW conversion.

EVLA detrimental threshold levels as a function of frequency and distance from the nearest antenna were calculated as follows:

1. The EVLA detrimental threshold levels were calculated for each frequency point using equation 8 of Rick Perley's VLA/VLBA Interference Protection Memo #34 (Power emitted in a bandwidth corresponding to a 3 Km/s velocity resolution source must be less than -180.6 + 30log(frequency in GHz) + 10log(Tsys in Kelvin)). The nominal receiver Tsys was used for each receiver band. This

equation calculates the EVLA detrimental threshold level in dBW, at a reference distance of 1 m.

2. A power spreading factor of 20*log(range, in meters) was applied to the results of 1, above, to project the detrimental levels over the representative 37m from the API antenna location nearest a EVLA antenna (see IP memo #34, section 4 discussion). The EIRP values may then be compared directly with the projected EVLA detrimental levels—these are the threshold curves plotted on the EIRP chart

Detailed Conclusions:

Figure 1 shows the insertion loss of the EVLA/ALMA reverberation chamber vs. frequency. This loss figure is added back in to the power detected at each frequency point in order to calculate the camera EIRP (see the "Data Analysis" section of this document for a detailed description of the data analysis procedure).

Figure 2 shows a previously recorded instrumentation noise floor and 40m EVLA detrimental levels. Since the instrumentation noise floor is from 5 to 10 dB above the 40m detrimental levels, it would be prudent to recommend mitigation measures, even for those frequency ranges where no emissions were seen above the instrumentation noise floor.

In order to assure that a worst case power level was seen, the reverberation chamber mode stirrer was left on (continuously rotating), while the spectrum analyzer, set to peak detector mode and max hold recorded the power peaks drifting through the receiving antenna location within the shielded chamber. Although this method is not typical for emissions measurements, it does provide a worst case value for measuring these narrow CW signals, widely spaced in frequency.

Figure 3 shows the peak RF emissions of the Orbital Research LNB1075S-500X-WN60 modified with a metal, spiral RFI gasket when the LNB cover was removed. Very strong emission from what appears to be the internal 2687.5 MHz oscillator was seen at that frequency, as well as the X2 and x3 harmonics (as well as the final, 10750 MHz LO frequency, and the 1250 MHz down-converted 12 GHz beacon frequency). As much as 50 dB of shielding is required to reduce these emissions down below the detrimental thresholds, although it should be noted that the actual, in-field emissions would be significantly lower, since these measurements are a worst case peak in the reverberation chamber.

Where the signal was not detected (950 MHz in this plot), the recorded value was set to an arbitrary value below the noise floor (-110 dBm), producing the EIRP values shown in the chart. This was done to distinguish detected signal levels from non-detections.

Figure 4 shows the peak RF emissions of the Orbital Research LNB1075S-500X-WN60 modified with a metal, spiral RFI gasket when the LNB cover was re-installed. Only the 12 GHz in-chamber beacon, down-converted to the 1250 MHz IF was still seen.

Where the signal was not detected (950, 2687.5, 5375, 8062.5, & 10750 MHz in this plot), the recorded value was set to an arbitrary value below the noise floor (-110 dBm), producing the EIRP values shown in the chart. This was done to distinguish detected signal levels from non-detections.

Figure 5 shows the peak RF emissions of the Orbital Research LNB1075S-500X-WN60 modified with ferrite, RF-absorbing pads when the LNB cover was removed. The results were very similar to those obtained with the previous LNB when it's cover was removed (though typically 5-10 dB weaker at most frequencies). As before, nearly 50 dB of shielding is required to reduce these emissions down below the detrimental thresholds, although it should be noted that the actual, in-field emissions would be significantly lower, since these measurements are a worst case peak in the reverberation chamber.

Where the signal was not detected (950 MHz in this plot), the recorded value was set to an arbitrary value below the noise floor (-110 dBm), producing the EIRP values shown in the chart. This was done to distinguish detected signal levels from non-detections.

Figure 6 shows the peak RF emissions of the Orbital Research LNB1075S-500X-WN60 modified with ferrite, RF-absorbing pads when the LNB cover was re-installed. The results were improved over the open-cover results, but around 30 dB of shielding would still be required to reduce these emissions down below the detrimental thresholds if these peak measurements were actually seen in the field.

Where the signal was not detected (950, 8062.5, & 10750 MHz in this plot), the recorded value was set to an arbitrary value below the noise floor (-110 dBm), producing the EIRP values shown in the chart. This was done to distinguish detected signal levels from non-detections.

Charts and Chart Descriptions:

Figure 1 (Background): A plot of the 0 – 20 GHz chamber IL data, showing the chamber and instrumentation loss for a transmitter located near the center of the transmitter end of the chamber. Since this calibration was performed using the Pomeroy antenna, the IL data is probably useful from upper VHF to 20 GHz. The trend-line equation format was set to maximum precision to reduce round-off errors. The yellow curve demonstrates that plotting the trendline equation re-generates the (black) trendline curve. (See “Data Analysis”, “ERP values…”, description 1, above, for a detailed discussion of the creation of this curve.)

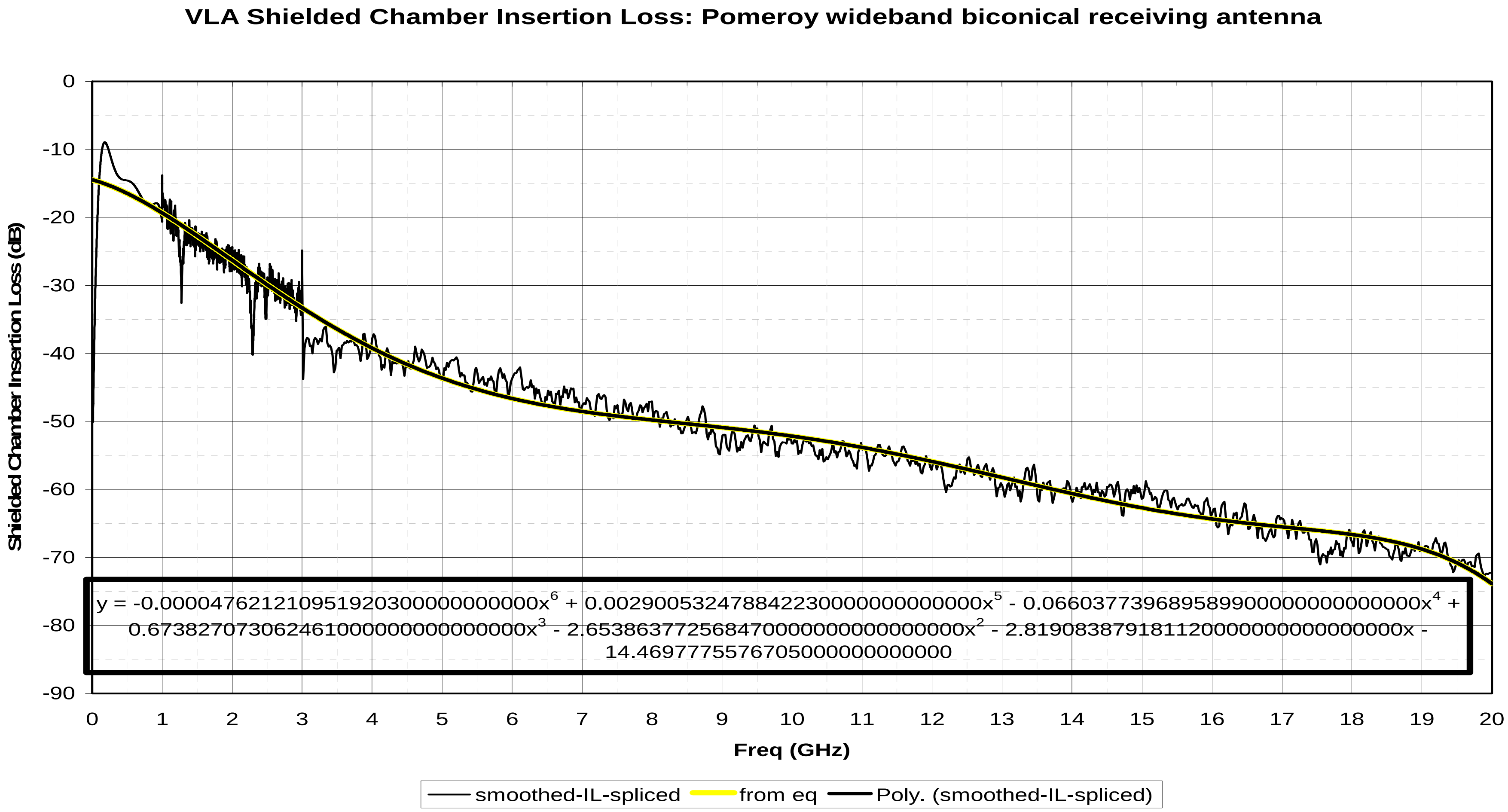


Figure 2: A typical chamber empty plot. The RFI @ 225 & 300 MHz from the mode tuner stepper motor controller, which is normally turned off during VHF/UHF data acquisitions.

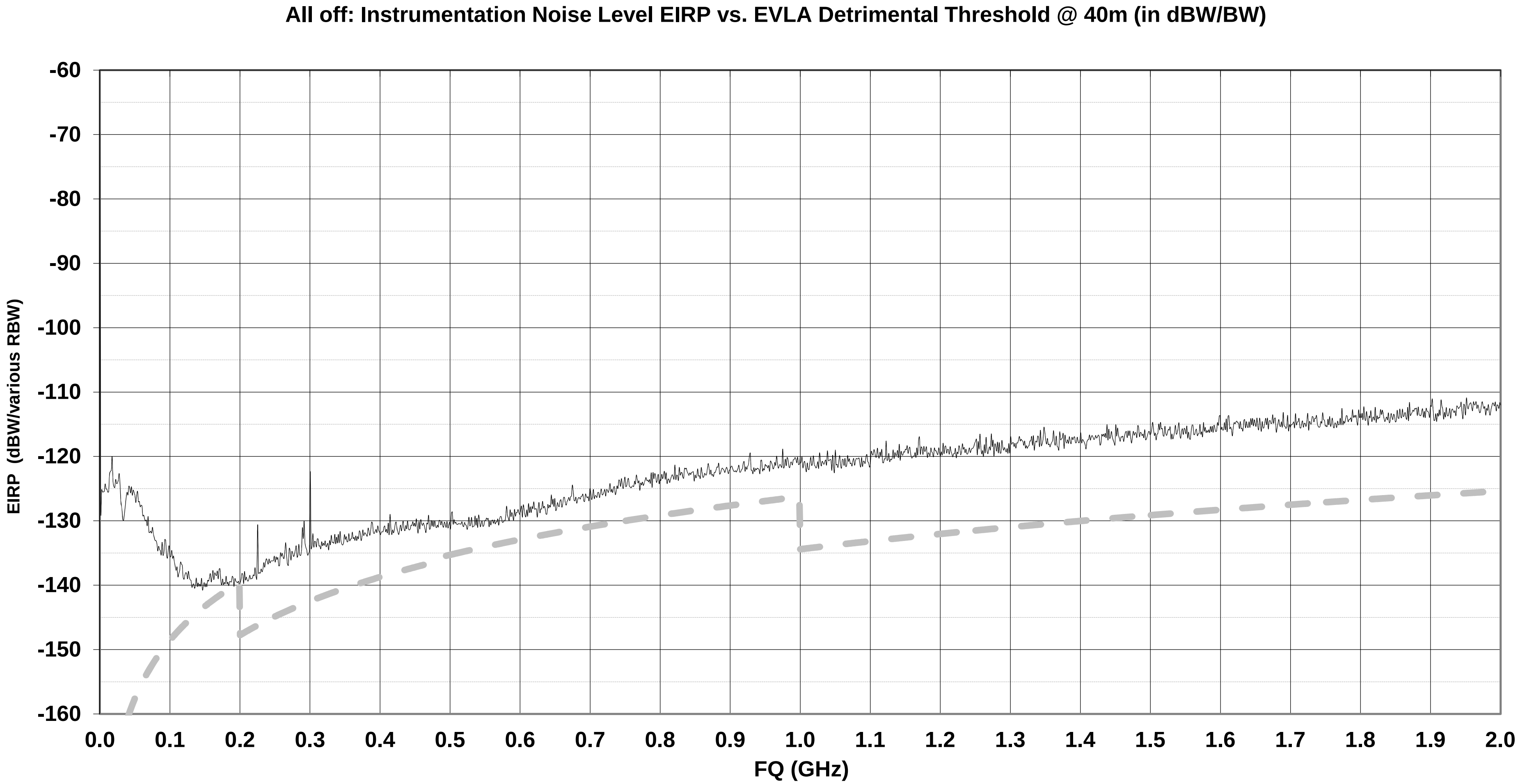
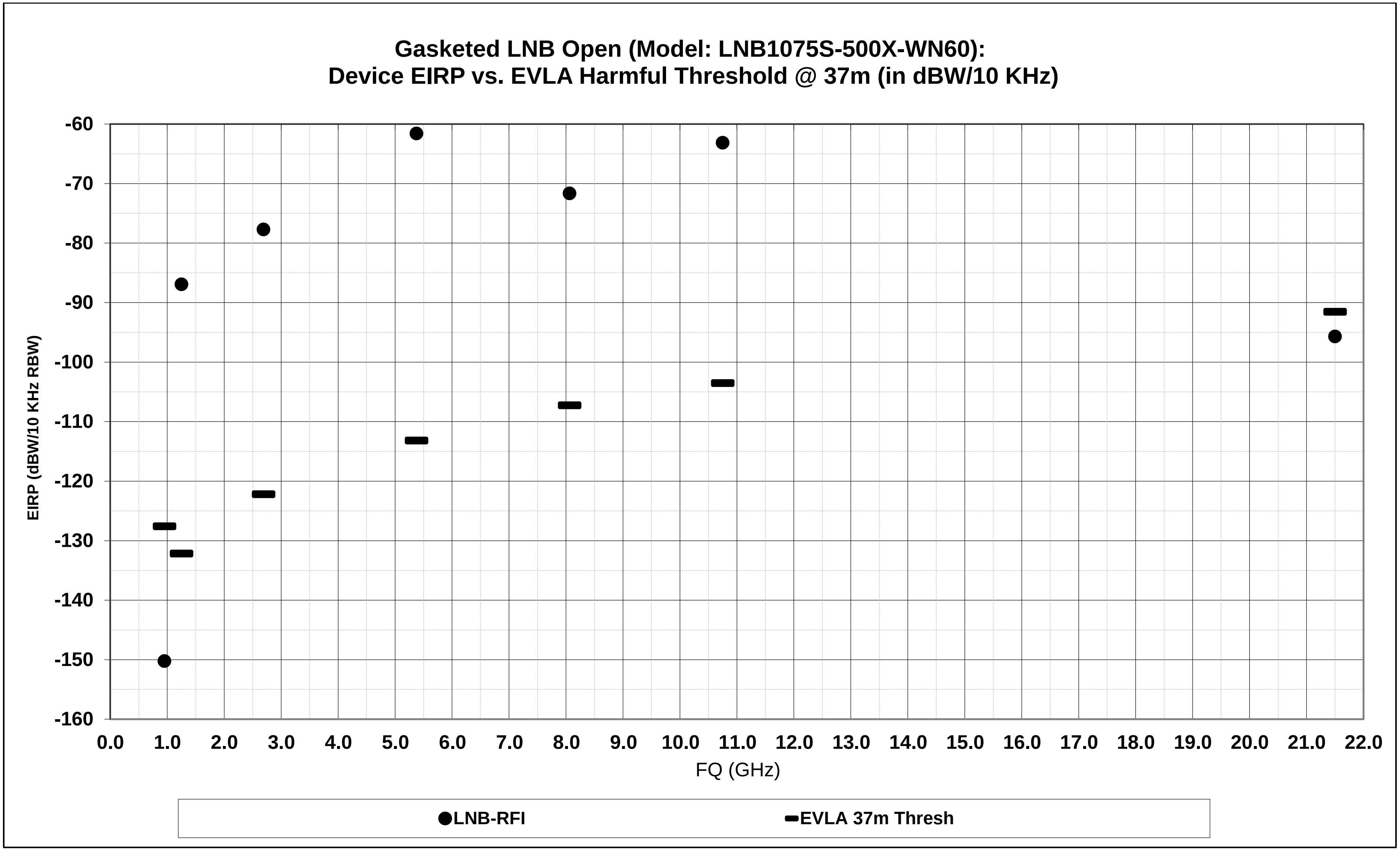


Figure 3: RF emissions (EIRP) from the spiral gasketed LNB (open), + the EVLA detrimental threshold translated 37m.



Gasketed LNB Open (Model: LNB1075S-500X-WN60):
Device EIRP vs. EVLA Harmful Threshold @ 37m (in dBW/10 KHz)
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
EIRP (dBW/10 KHz RBW)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
21.0
22.0
FQ (GHz)
LNB-RFI
EVLA 37m Thresh

Figure 4: RF emissions (EIRP) from the spiral gasketed LNB (closed), + the EVLA detrimental threshold translated 37m.

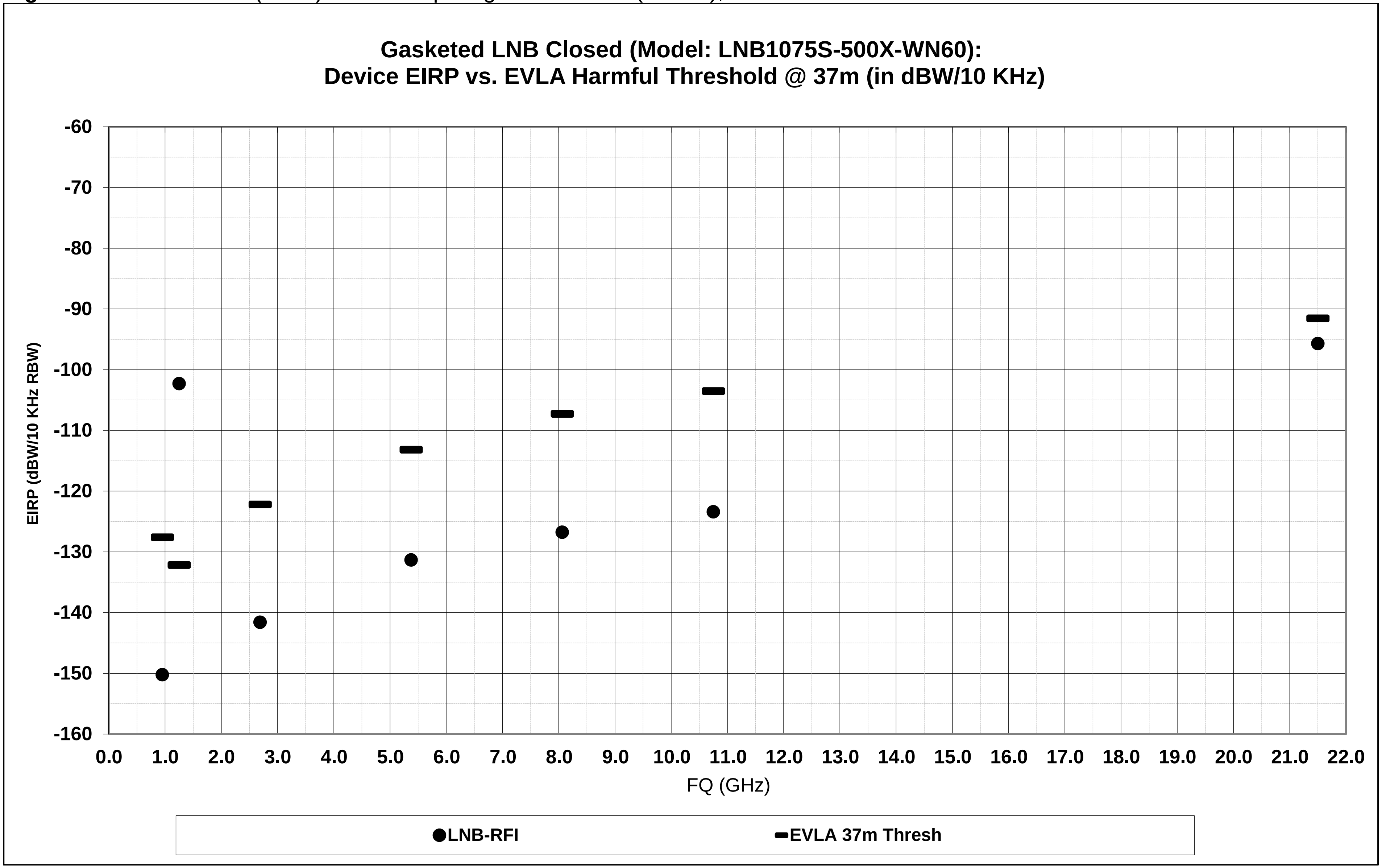


Figure 5: RF emissions (EIRP) from the ferrite-loaded LNB (open), + the EVLA detrimental threshold translated 37m.

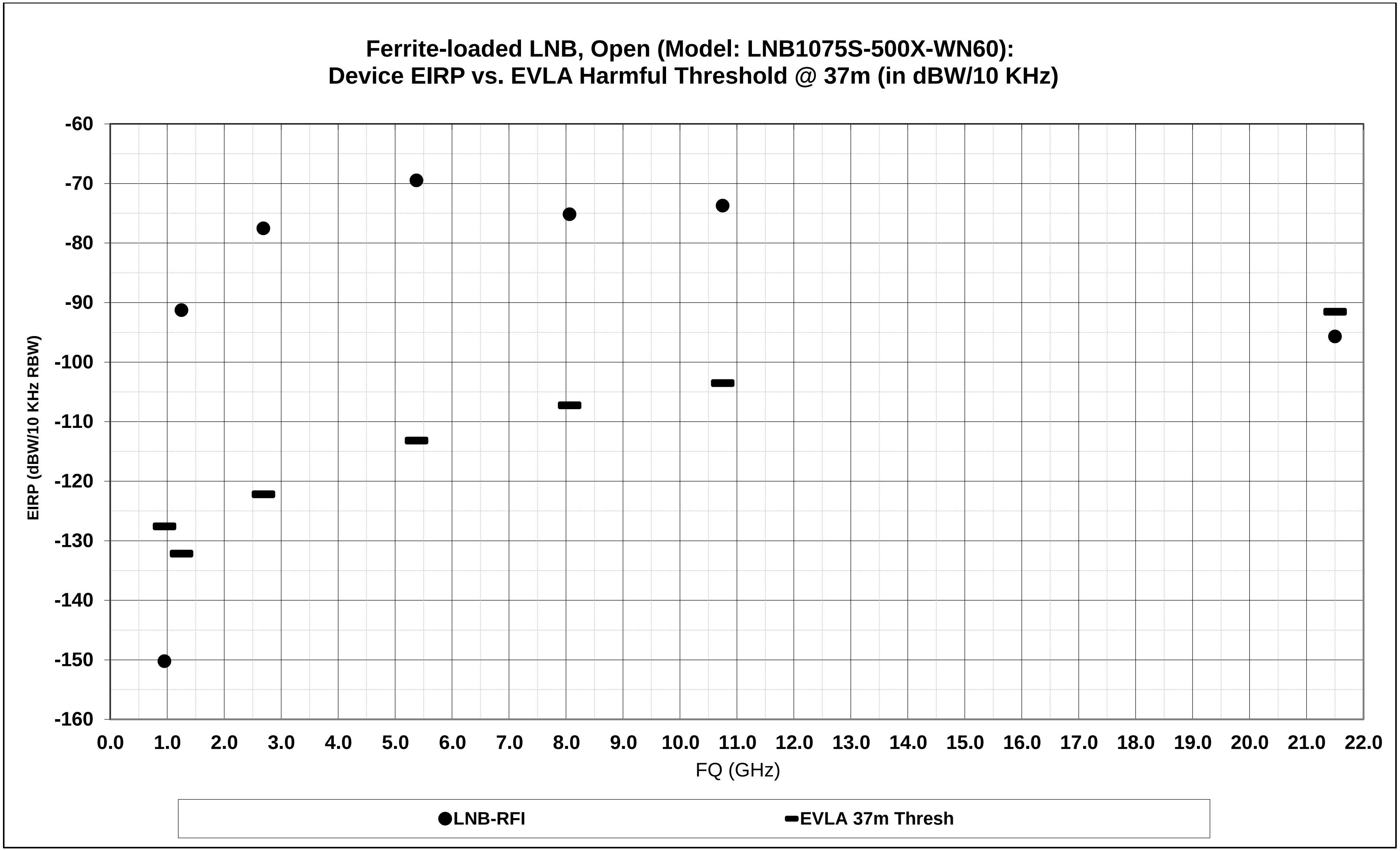


Figure 6: RF emissions (EIRP) from the ferrite-loaded LNB (closed), + the EVLA detrimental threshold translated 37m.