LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

LIGO-T050268-00-C *LIGO* 22 December 2005

LSC Detection Chain Linearity Measurements

Richard Abbott, Ben Abbott

Distribution of this document:
LIGO Science Collaboration

This is an internal working note
of the LIGO Project.

California Institute of Technology
LIGO Project – MS 18-34
1200 E. California Blvd.
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project – NW17-161
175 Albany St
Cambridge, MA 02139
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

LIGO Hanford Observatory
P.O. Box 1970
Mail Stop S9-02
Richland WA 99352
Phone 509-372-8106
Fax 509-372-8137

LIGO Livingston Observatory
P.O. Box 940
Livingston, LA 70754
Phone 225-686-3100
Fax 225-686-7189

http://www.ligo.caltech.edu/

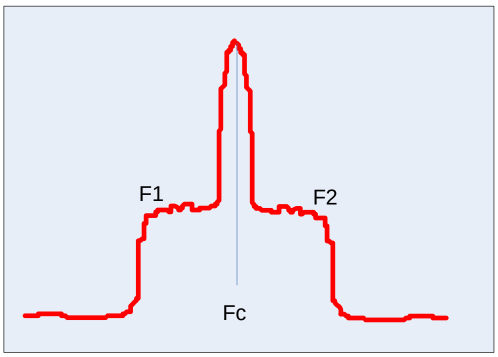
1. Test Overview

In a recent test documented in T050268-00-C, a series of two-tone intermodulation measurements were performed on the LSC I&Q Demodulator board. In this note, the search for nonlinearities has been expanded to include the LSC RF Photo-detector (RFPD) module.

In evaluating the detection chain components consisting of the RFPD and the Demodulator board, two-tone data was taken with the hope of making extrapolations to the case of highly-shaped, band-limited noise similar to the LIGO low frequency noise spectrum.

Using predictions from relevant literature, the results of the two tone measurements seemed to imply the possibility of significant non-linear behavior in the detection chain. A second test was devised using an RF carrier, amplitude modulated with band limited noise to see if there was agreement between theory and practice. The modulated RF spectrum resembles Figure 1.

Figure 1 Carrier with AM noise modulation



The upper and lower shoulder frequencies at F1 and F2 are each 20 Hz from the RF carrier center frequency of 25.1 MHz

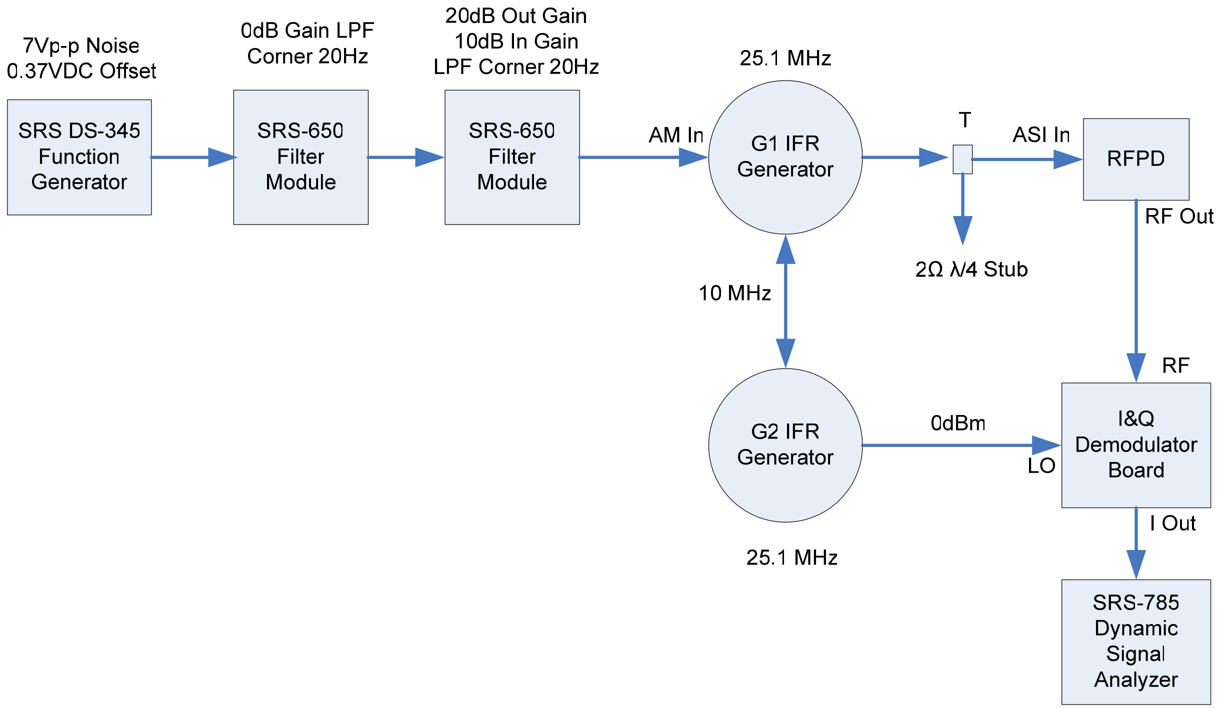
This amplitude modulated RF carrier was applied to the ASI input of the RFPD and was synchronously demodulated using the LSC Demodulator board in its normal operating configuration.

For reasons not presently understood, the predictions from the two-tone measurements don't agree with the band limited noise measurement. As the band-limited noise test more closely approximates the LIGO operating mode, it is felt that these results are more reliable. The band-limited noise results show no measurable non-linear up-conversion to a level of ~70dB less than the applied noise. This is more clearly depicted in the data plots that follow.

2. Test Setup

An overall view of the test setup is shown in Figure 2.

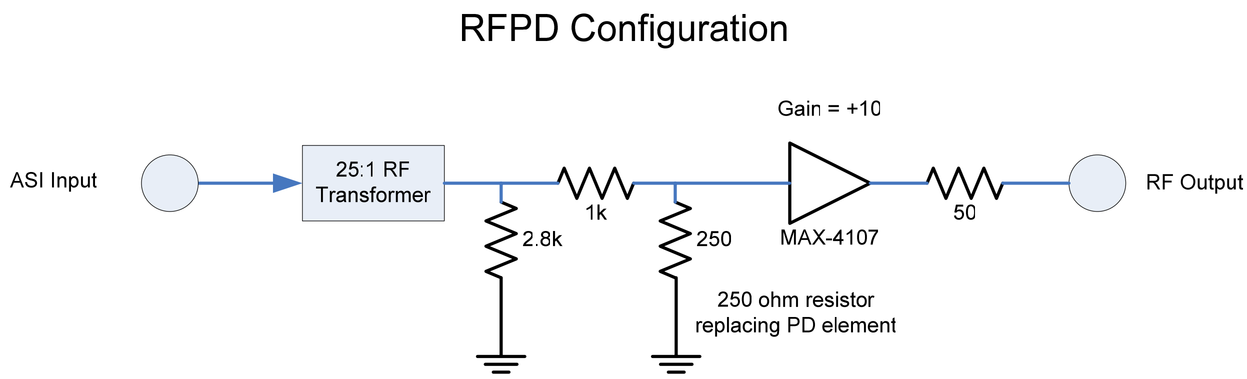
Figure 2 Test Setup



The gain from the ASI input to the RF output of the RFPD is approximately 10dB for this configuration. The second generator, G2, was phase-adjusted to peak the DC voltage at the I-output of the Demodulator board. This phase relationship provides maximum sensitivity to AM.

Figure 3 shows the configuration for the RFPD used during the test. The InGaAs photo-detector element was replaced with a 250 ohm resistor to provide a simpler test of the MAX-4107 output amplifier. The relatively small dynamic range of this amplifier had made it a possible candidate for contribution to system non-linearity.

Figure 3



3. Results

Figure 4 shows the band-limited noise spectrum applied to the AM input of the RF generator

Figure 4

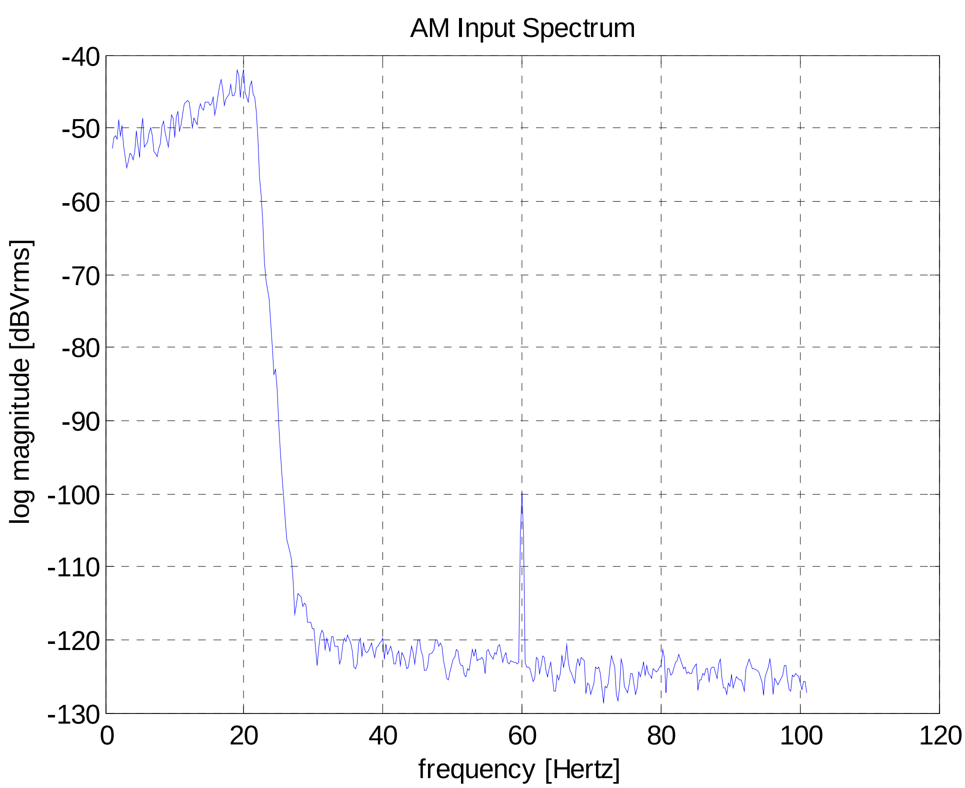
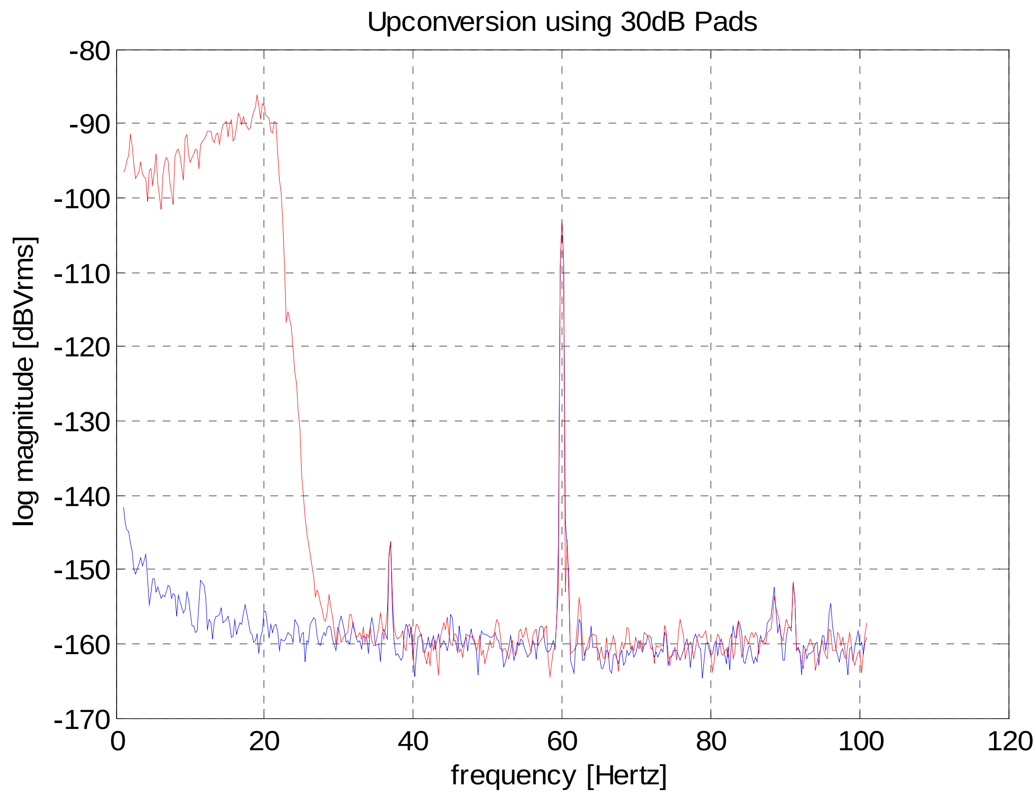


Figure 5 shows the demodulated spectrum as measured using the dynamic signal analyzer at the I-output of the Demodulator board. The output of the AM modulated generator, G1 in the diagram, has been attenuated by 30dB providing an RF level at the ASI input of approximately -32dBm.

The RF level at the input to the Demodulator was about -20dBm, and the detected DC level at the I-output was -8.5mVDC.

Figure 5



Any evidence of non-linear up-conversion would be seen as a replication of the low frequency noise in the 0-20Hz band being mirrored at a lower level in the 20-40Hz band. This plot shows no up-conversion within the ~70dB dynamic range of the measurement.

The blue curve in this and each of the following plots is the measurement noise floor produced when the AM input to G1 is turned off.

Figure 6 shows the demodulated spectrum at the I-output with 20dB of attenuation on G1 RF-output. (Measurement noise floor is shown in blue).

The RF level at the input to the Demodulator was about -10dBm, and the detected DC level at the I-output was -28.2mVDC

Figure 6

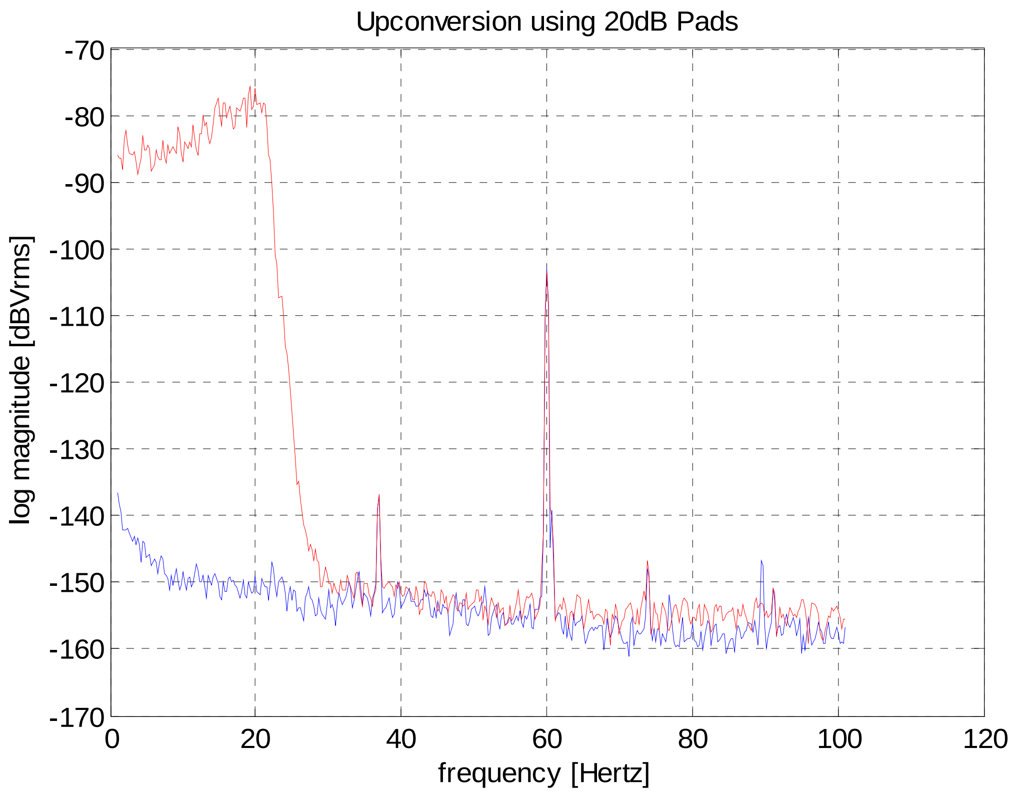


Figure 7 shows the demodulated spectrum at the I-output with 10dB of attenuation on G1 RF-output. (Measurement noise floor is shown in blue).

The RF level at the input to the Demodulator was about 0dBm, and the detected DC level at the I-output was -91.7mVDC. Still no obvious evidence is seen of up-conversion. This level is a common operating power for the AS-port photodiodes.

Figure 7

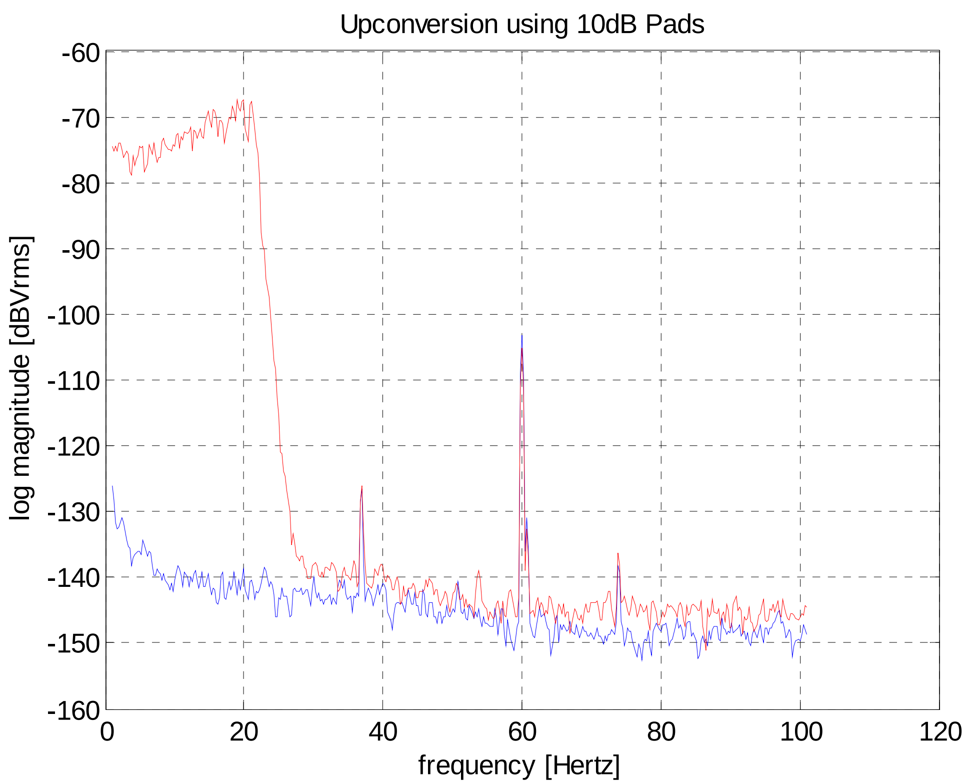


Figure 8 shows the demodulated spectrum at the I-output with 6dB of attenuation on G1 RF-output. (Measurement noise floor is shown in blue). An imaginative eye might claim that there is a small amount of up-conversion visible in the 20-40Hz band.

The RF level at the input to the Demodulator was about 4dBm, and the detected DC level at the I-output was -150mVDC.

Figure 8

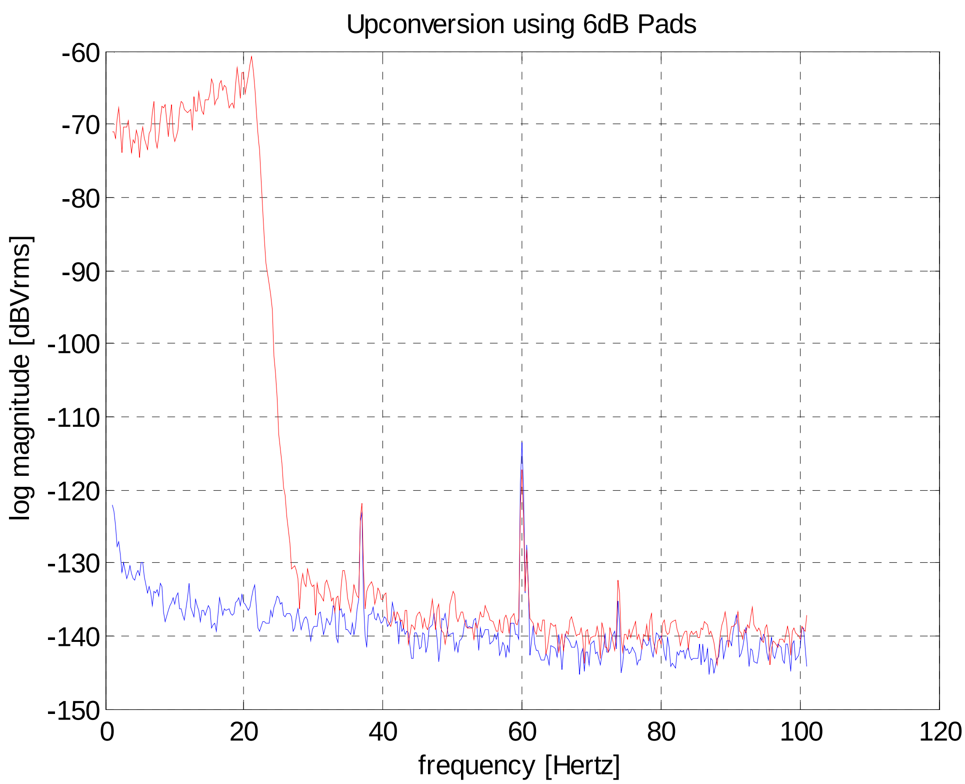
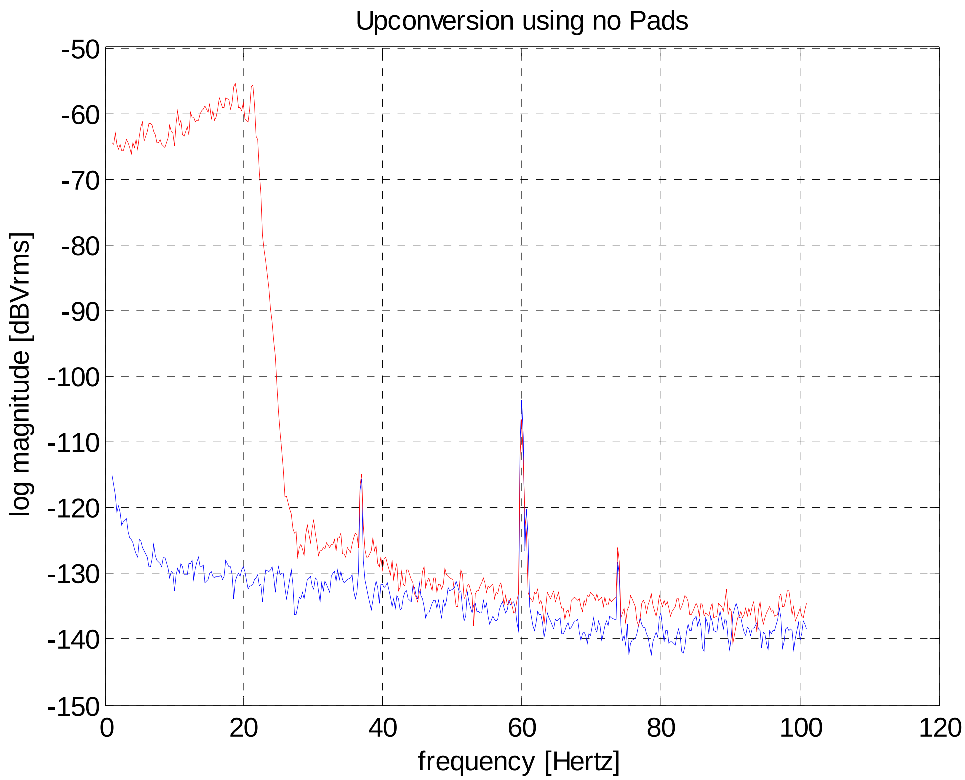


Figure 9 shows the demodulated spectrum at the I-output with 0dB of attenuation on G1 RF-output. (Measurement noise floor is shown in blue). Up-conversion is just visible in the 20-40Hz band.

The RF level at the input to the Demodulator was about 10.8dBm, and the detected DC level at the I-output was -334mVDC.

Figure 9



4. Conclusion

Within the dynamic range of the measurement, the combination of the RFPD output amplifier and the LSC Demodulator board do not show significant non-linear up-conversion. Only at the high end of the applied signals does the up-conversion become measurable using this technique, and this regime is a factor of several above the normal operating point as determined from the ASPD time-series data. The search for non-linear components must be broadened to include the photo-detector element in order to be thorough. This is a more difficult measurement that will involve light. Data must also be taken on the other elements in the LSC system including the whitening and de-whitening electronics, the DAC output and the Coil Driver module.