LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

LIGO-T050260 -00-C *LIGO* 02 December 2005

LSC Demodulator 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

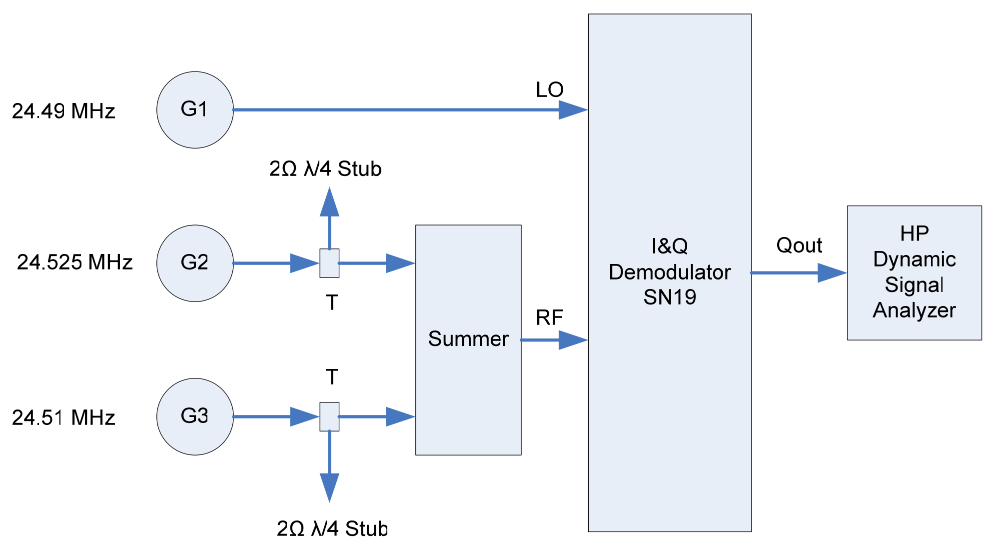
Recent observations have suggested the possibility of non-linear mechanisms in the LSC demodulator chain contributing to up-conversion of low frequency interferometer noise. Candidate components include the LSC photo-detector element, the MAX-4107 operational amplifier, the LSC Demodulator board mixers and other post detection electronics.

As a first step to quantifying the non-linearity of the above components, a test has been performed to measure the linearity of the LSC Demodulator board (D990511) under conditions similar to those encountered at the observatories. The test consists of simultaneously applying two pure RF tones to the demodulator, and looking for telltale third order intermodulation products.

As it is the goal to measure small non-linear effects, care was taken to ensure that the test setup did not itself introduce non-linearities.

2. Test Setup

The diagram below details how three signal generators were used to provide the needed signals for the measurement. Generator G1 is used as the local oscillator for the demodulator board under test. Two closely spaced (15 kHz apart) RF tones are supplied by generators G2 and G3.



Ideally, the resultant spectrum as viewed on the HP dynamic signal analyzer (DSA) would consist of the demodulated signals from G2 and G3, and should appear as two sine wave peaks at 20 kHz and 35 kHz respectively.

20 kHz from the difference component of G1 and G2

35 kHz from the difference component of G1 and G3

Any non-linearity in the detection process will generate cross products, some of which will be observable within the 100 kHz bandwidth of the DSA. This test focuses on the third order intermodulation products of G2 and G3. Within the DSA bandwidth these products are a result of:

$$IP3_1 = 2*G2-G3$$

$$IP3_2 = 2*G3-G2$$

An RF spectrum analyzer was used to verify that no measurable third order products were visible prior to applying the two tones to the demodulator board. Care must be taken that the input attenuators integral to the RF spectrum analyzer are set properly to avoid overdriving the analyzer and producing misleading third order products.

Second harmonics of G2 and G3 were reduced to less than -70 dB relative to the fundamental by use of open ended quarter wave stubs. The generators G2 and G3 were checked for intermodulation at their highest level (13 dBm), and also at several lower output power levels.

3. Results

Table 1 shows the measurement data. The first column is the RF amplitude setting of the generators, G1 and G2. Both generators were set to the same level during the measurement.

The second column gives the RF level of one of the two tones incident on the demodulator board. This reflects the power lost due to cable and power combiner losses intrinsic to the test setup.

The third and forth columns show the magnitude of the detected tones as measured by the DSA. These magnitudes are converted to dBm in the fifth and sixth columns for convenience in relating signal levels.

Table 1

G1, G2 RF Level (dBm)	Power Incident on Demodulator Board (dBm)	20 kHz Signal Level (dBVrms)	Third Order (5 kHz) Level (dBVrms)	Calculated 20 kHz Signal Level (dBm)	Calculated Third Order (5 kHz) Signal Level (dBm)
13	7.8	-16	-49.8	-2.99	-36.79
10	4.8	-19	-59.4	-5.99	-46.39
9	3.8	-20.1	-62	-7.09	-48.99
8	2.8	-21.1	-64.4	-8.09	-51.39
7	1.8	-22	-66.6	-8.99	-53.59
6	0.8	-23.1	-68.5	-10.09	-55.49
5	-0.2	-24.1	-70.7	-11.09	-57.69
4	-1.2	-25.1	-72.6	-12.09	-59.59
3	-2.2	-26.1	-74.6	-13.09	-61.59
0	-5.2	-29.2	-81.3	-16.19	-68.29
-3	-8.2	-32.1	-88.2	-19.09	-75.19
-6	-11.2	-35	-95.3	-21.99	-82.29
-9	-14.2	-38	-102.8	-24.99	-89.79
-12	-17.2	-41	-112.5	-27.99	-99.49
-15	-20.2	-44	-116.8	-30.99	-103.79

Figure 1 shows the power incident on the demodulator board vs. the power of the fundamental (20 kHz) and third order product (5 kHz). In reality, the actual power incident on the Q-phase mixer is 3dB plus insertion loss less than the power incident on the board. This is due to the power splitter used to drive the I and Q mixers (Mini-circuits Inc. JMS-17 mixers) from the incoming RF signal.

Figure 1