LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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ISS SN115 LLO Installation Notes

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1 Overview

During mid August 2005 the Intensity Stabilization Servo (ISS) was replaced at LIGO Livingston Observatory (LLO). The previously installed servo (SN01) was a prototype of the final design and had become outdated. The replacement servo (SN115) has upgraded Data Acquisition (DAQ) interfaces and has lower noise and higher slew rate overall. SN115 is a revision D2 design (LIGO-D02041-D2-C) the numerous component changes, and release for site operation, are documented by DCN E050199-00-C.

SN115 ISS was tested and found to be in conformance with the revised test procedure (LIGO-T030184-A-C). The completed test procedure, an up-to-date schematic and an electronics traveler were given to LLO site personnel for local documentation.

The following document contains the notes associated with the installation of SN115 as well as documentation of SN01 prior to its removal.

2 Summary of replacement process and goals

2.1 Goals

2.1.1 Increase in light levels incident on photo-detectors

The original servo, SN01, had a factor of 10 reduction in optical power that was implemented by an ND-10 Neutral Density Filter. ISS SN01 would not properly operate above 0.4 volts of detected light. The reason for this was unknown as the installation began. It was desired that this problem be fixed and the detected light levels be increased by a factor of 10.

2.1.2 Increase in servo bandwidth

Measurements confirmed that the unity gain frequency of the installed SN01 servo was ~20kHz. A unity gain frequency of at least 100kHz was desired.

2.1.3 Improved Relative Intensity Noise (RIN) suppression

As an outgrowth of the limited gain and lower than design optical levels, the relative intensity noise was approximately an order of magnitude higher than desired.

2.1.4 Increased Data Acquisition (DAQ) gain

The gain on channels used to remotely monitor RIN was too low to adequately measure RIN. It was a goal to accurately measure RIN on these channels.

2.2 Actions taken

2.2.1 Transfer Functions

Before replacement of SN01, a detailed analysis had to be performed to record its operating parameters. The following data were recorded on SN01 during normal operating conditions (6dB slider gain on control screen, 0.4 volts detected light levels on both inside and outside the loop photo-detectors).

- Out-of-loop and in-the-loop relative intensity noise (RIN) from 8 Hz to 100kHz
- Actuator drive spectra for the “current shunt drive”
- Servo open loop transfer functions from 10Hz to 10MHz
- High frequency noise spectra above 100kHz
- RMS drive levels represented by time series of actuator drive signals

An identical set of data was taken on the replacement servo, SN115 as well as a careful check for oscillations at all relevant points of the system using an oscilloscope.

2.2.2 Component Changes

- There are many Analog Devices AD-829 Operational Amplifiers (Op-amps) used to implement the servo transfer function. This type of op-amp requires the use of frequency compensation in the form of a capacitor, the size of which is determined by the closed loop gain configuration. By consulting the data sheet, more appropriate values were determined that result in higher bandwidth and slew rate. All changes are noted in the DCN and are reflected on the revised schematic.
- In response to the lower than required gain on the DAQ read-back channels, the gain was increased on U45 and U55 from 10 to 100. The poles and zeros remain the same for these whitened DAQ channels.
- Other changes to component values that don’t have immediate effect on the operation of the servo are reflected in the DCN, E050199-00-C.

3 Measured Transfer Functions and Spectra

The following sections detail the measurements taken on the old and new system. Effort is made to overlay the data such that operational differences are apparent. The data are corrected for RIN and should be readily interpretable.

The system conditions during spectral analysis and transfer function analysis are as follows:

3.1 ISS SN01

- Gain Slider set to 6dB
- ND10 filter in place

- 0.4 volts detected optical power at BNC monitoring points for both in and out of the loop photodetectors.
- Outer loop components not active, control only on inner loop servo function
- Optical pick-off after PMC cavity just prior to IOO EOMs and motorized wave plate

3.2 ISS SN115

- Gain Slider set to 20dB
- ND10 filter removed for higher optical power
- 3.65 volts detected optical power at BNC monitoring points for in the loop photodetector, 3.57 volts for out-of-loop photodetector.
- Outer loop components not active, control only on inner loop servo function
- Optical pick-off after PMC cavity just prior to IOO EOMs and motorized wave plate

3.3 Transfer Functions

3.3.1 10Hz to 100kHz Open Loop Transfer Function

Figure 1 and Figure 2 show the open loop transfer functions derived from the closed loop response as measured by the SR785 Dynamic Signal Analyzer at the test out channel 1 and 2 BNC ports. Signal injection was via the J4 analog excitation input

Figure 1

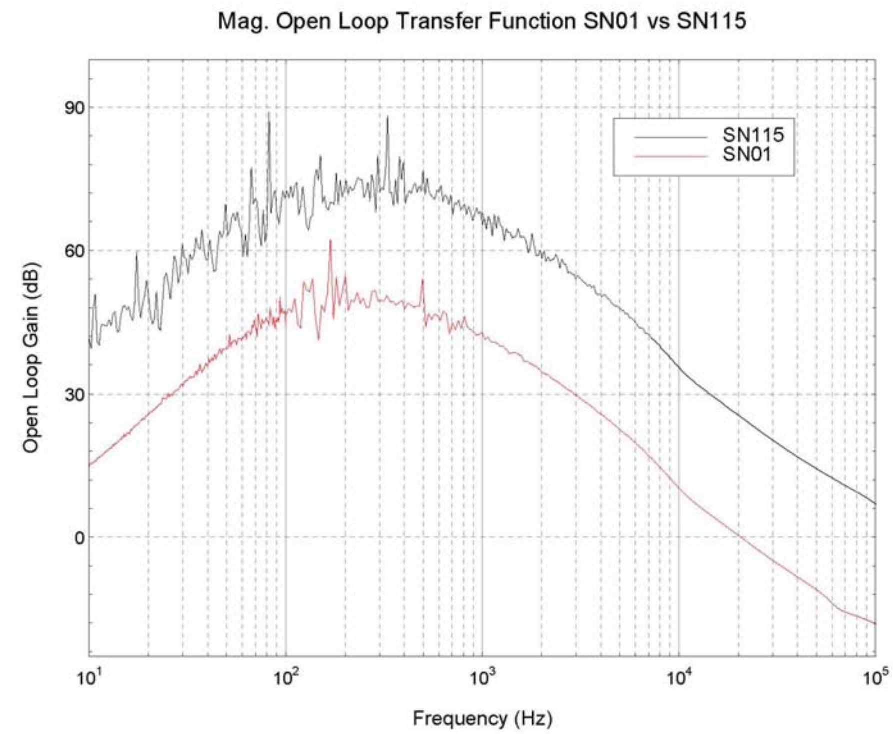
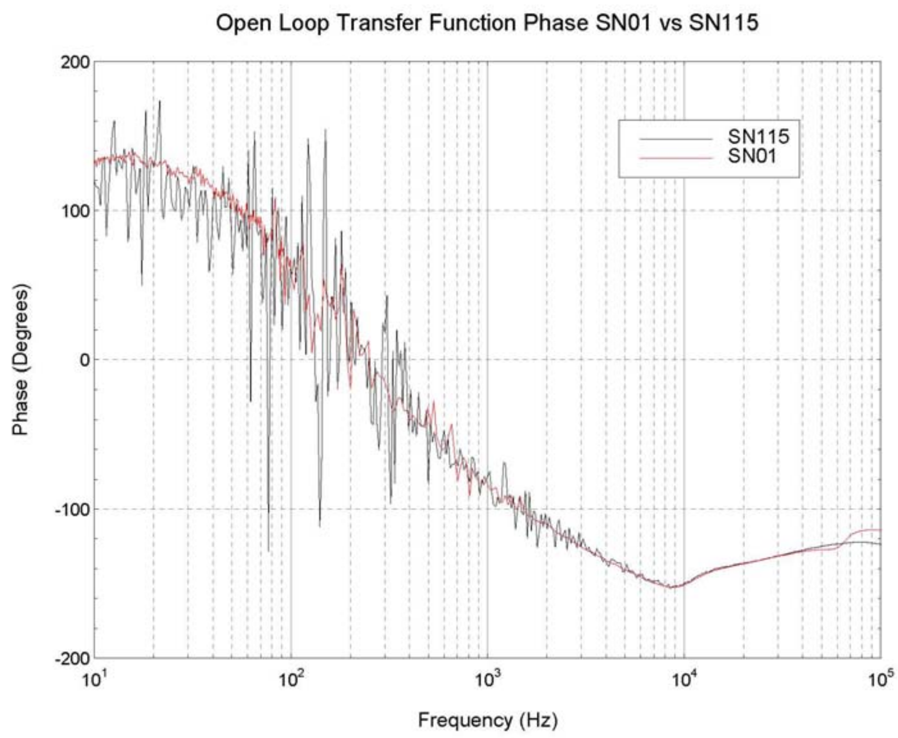


Figure 2



3.3.2 1kHz to 10MHz Open Loop Transfer Function

Figure 3 and Figure 4 are data taken with HP Network Analyzer. SN01 data is questionable above 500kHz due to low light levels.

Figure 3

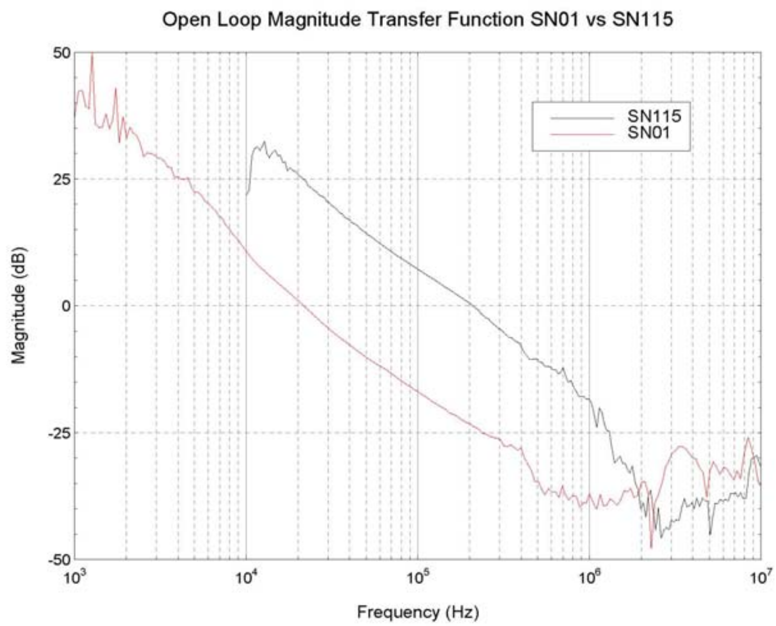
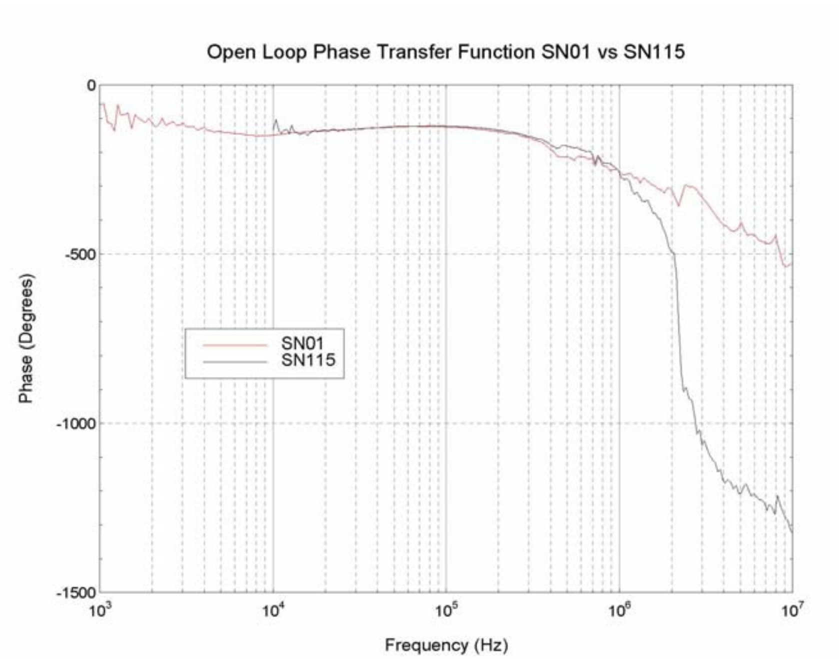


Figure 4

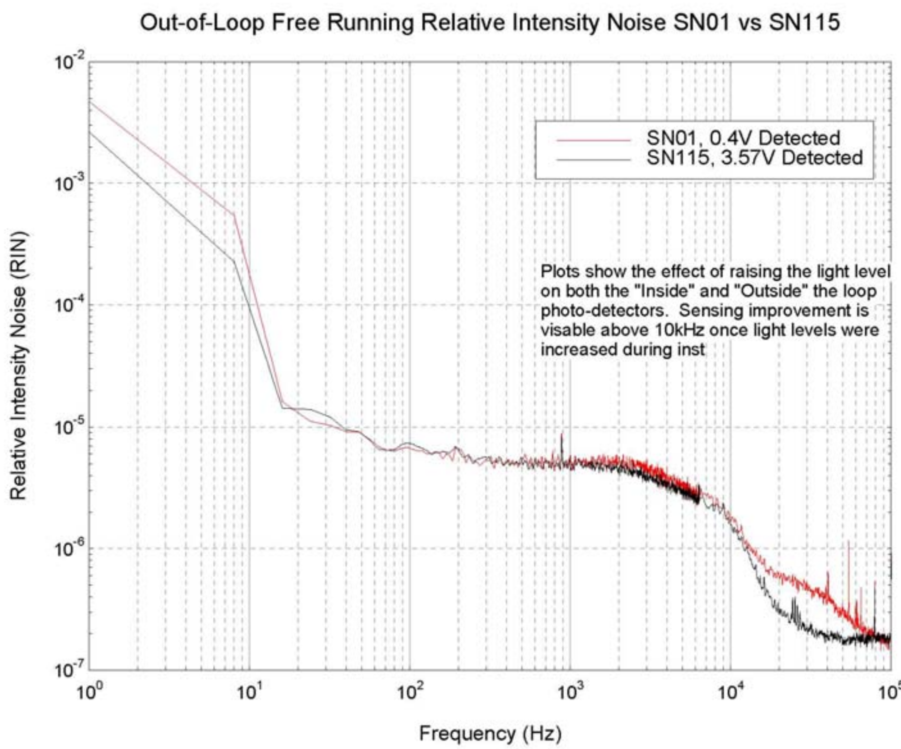


3.4 Spectral Analysis Data

3.4.1 Free Running RIN

Figure 5 shows the free running relative intensity noise at JTC1 and JTC8 before and after increasing the optical power as part of the installation of ISS SN115

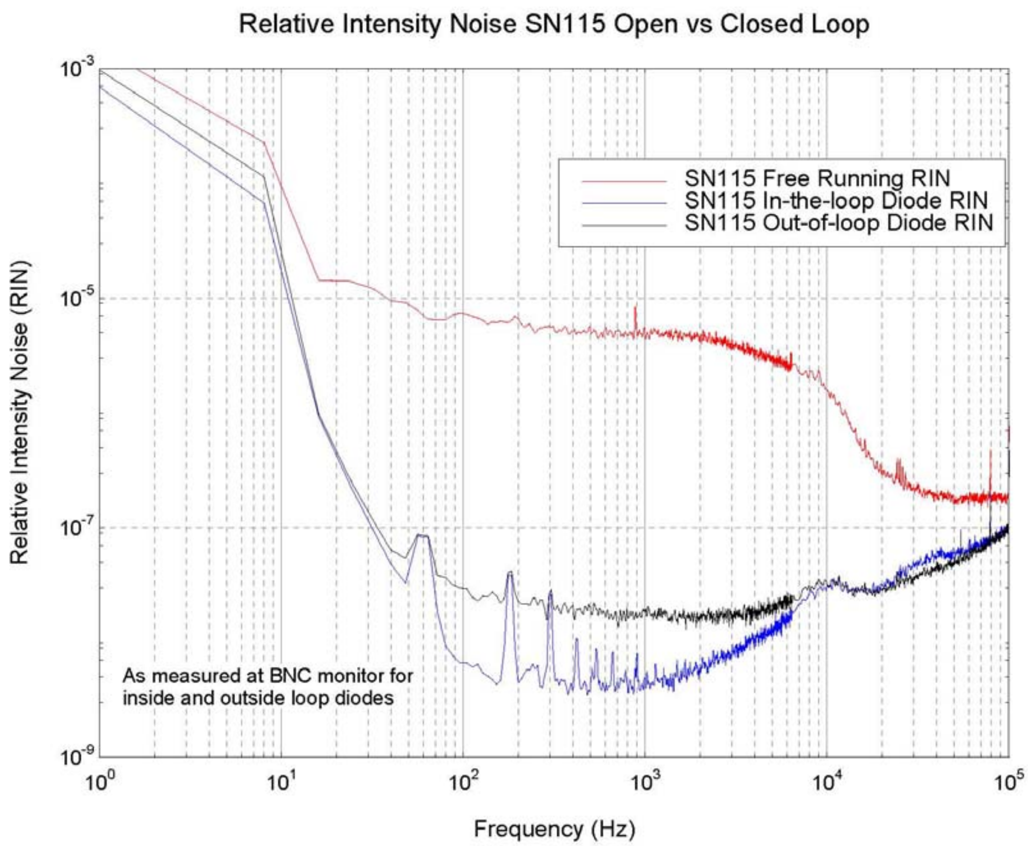
Figure 5



3.4.2 Open vs. Closed Loop RIN

Figure 6 shows a comparison between open and closed loop intensity noise suppression for ISS SN115. An overlay of the in-the-loop diode is provided to identify the point of gain limitation on the out-of-loop RIN.

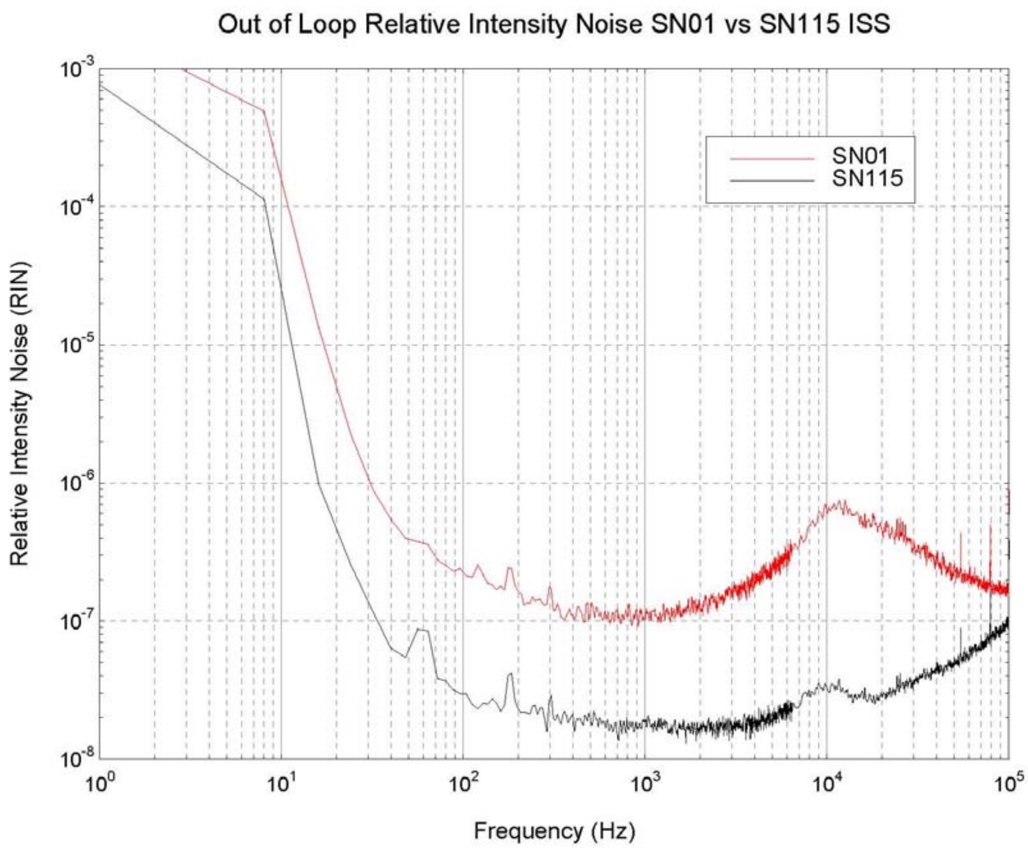
Figure 6



3.4.3 Out-of-loop RIN Comparison SN01 vs. SN115

A measurement was taken at SN115, JTC8 BNC and its SN01 equivalent of the out-of-loop suppressed RIN before and after installation of SN115. Figure 7 shows those results. The peaking in the SN01 curve is attributable to the lower unity gain frequency of 20kHz for this unit.

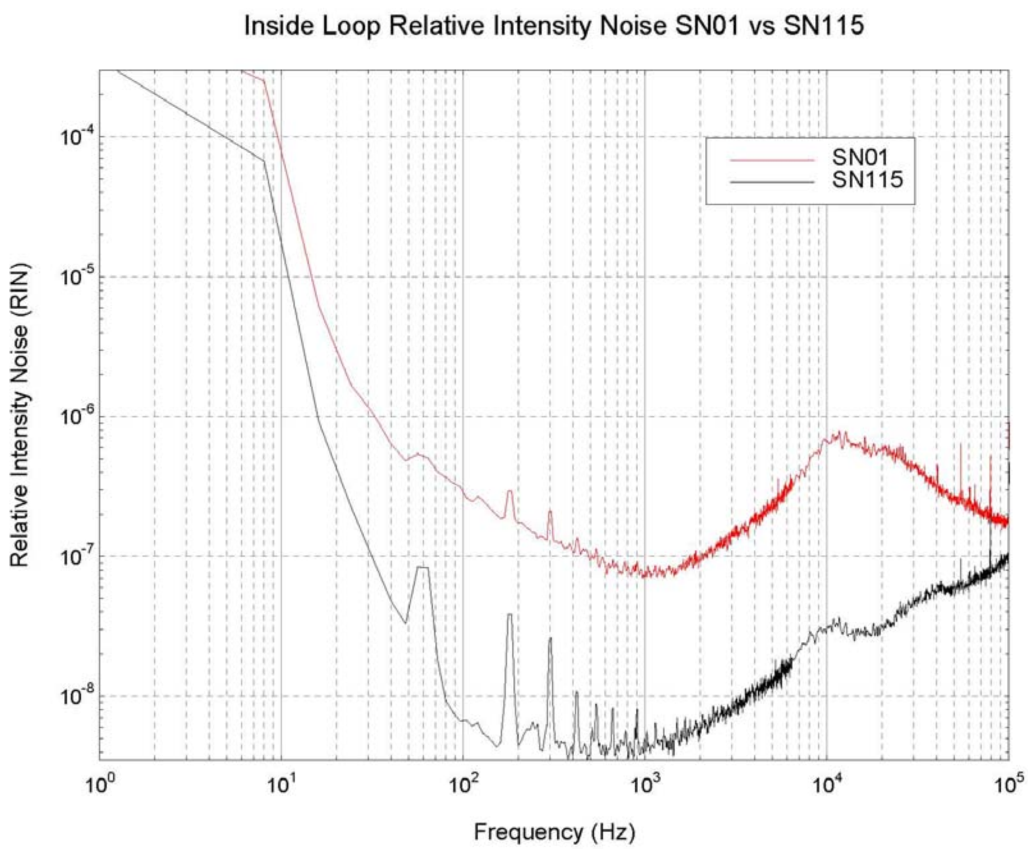
Figure 7



3.4.4 In-the-loop RIN Comparison SN01 vs. SN115

The same measurement as taken in Figure 7 was repeated for the in-the-loop monitoring point JTC1 BNC. The results are shown in Figure 8

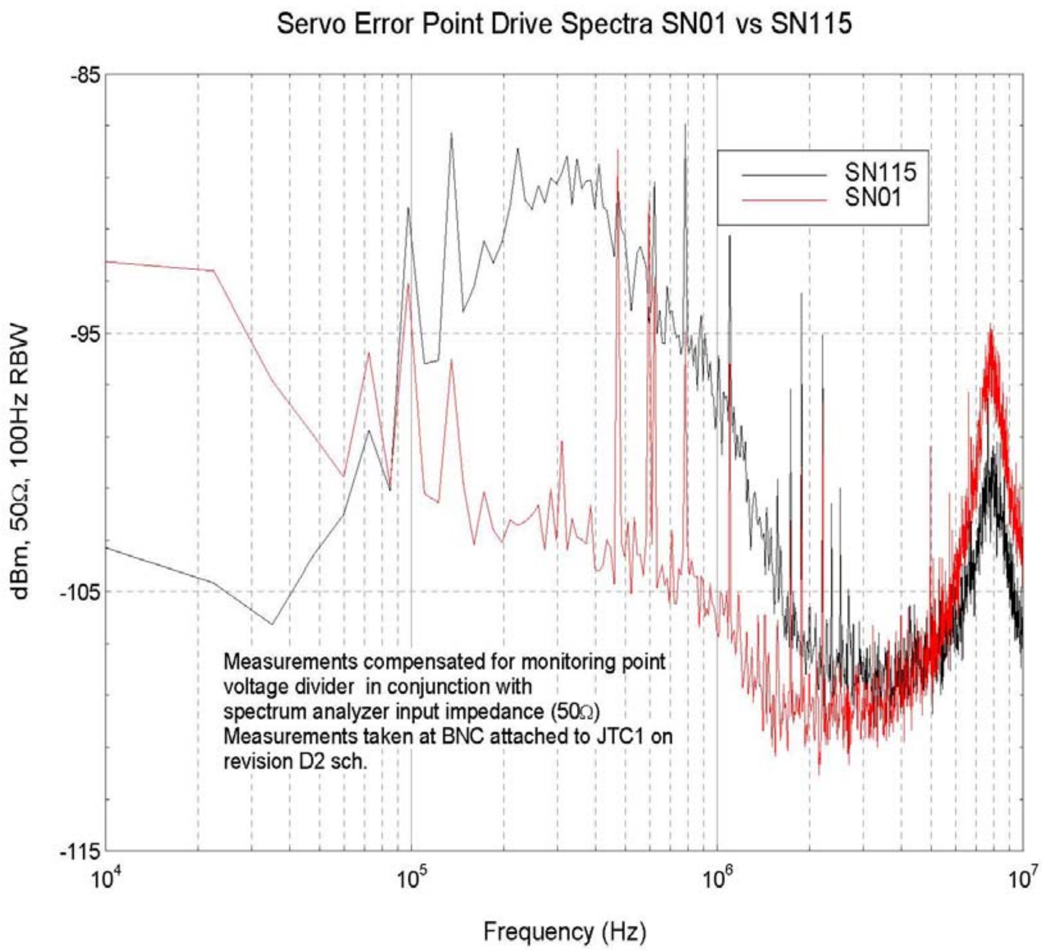
Figure 8



3.4.5 Servo Error Point Spectra

Figure 9 shows the spectrum at SN115 JTC1 BNC and its equivalent on SN01 during normal operating conditions. This is the in-the-loop diode spectrum. The peaking at ~8MHz is believed to be attributable to the photodiode head, not the light. This needs to be verified by measurement.

Figure 9



3.4.6 Current Shunt Drive Spectra

Figure 10 and Figure 11 show a comparison of the low and high frequency spectra of SN115 and SN01 current shunt drive taken during normal servo operation.

Figure 10

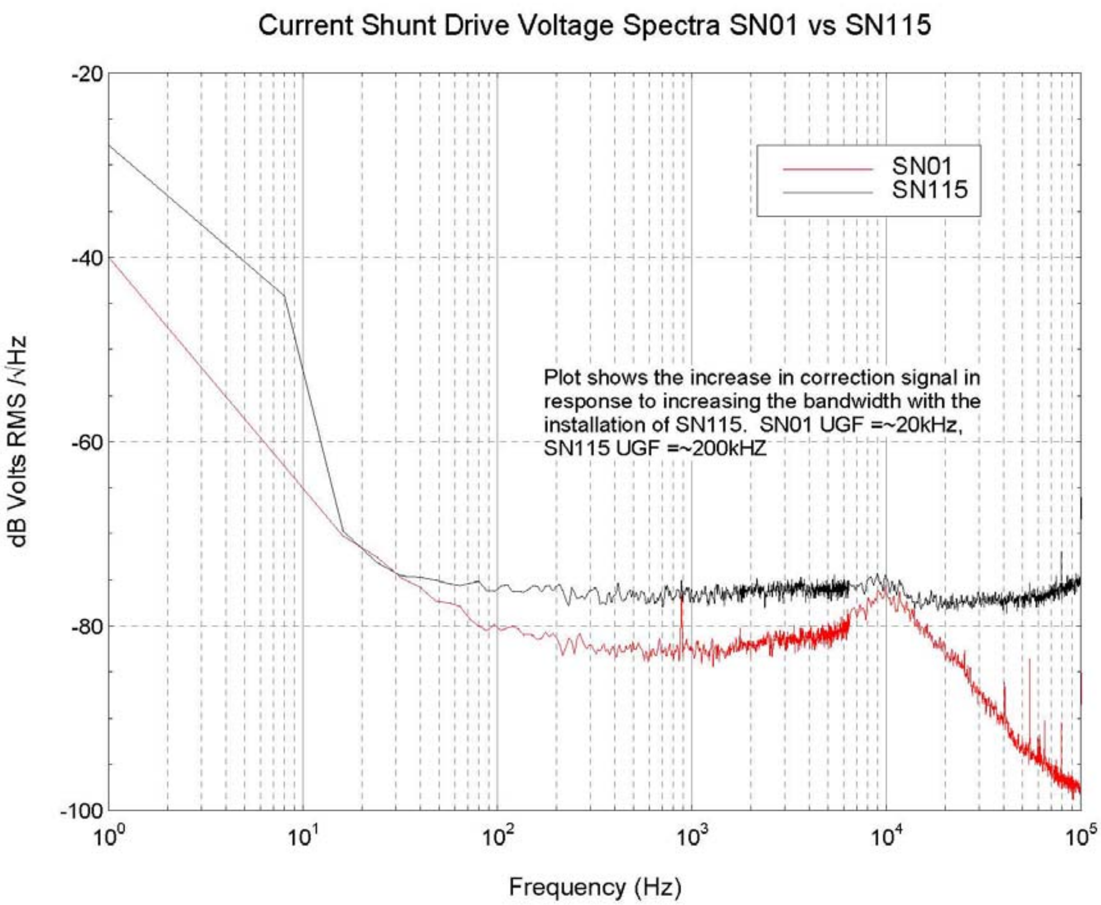
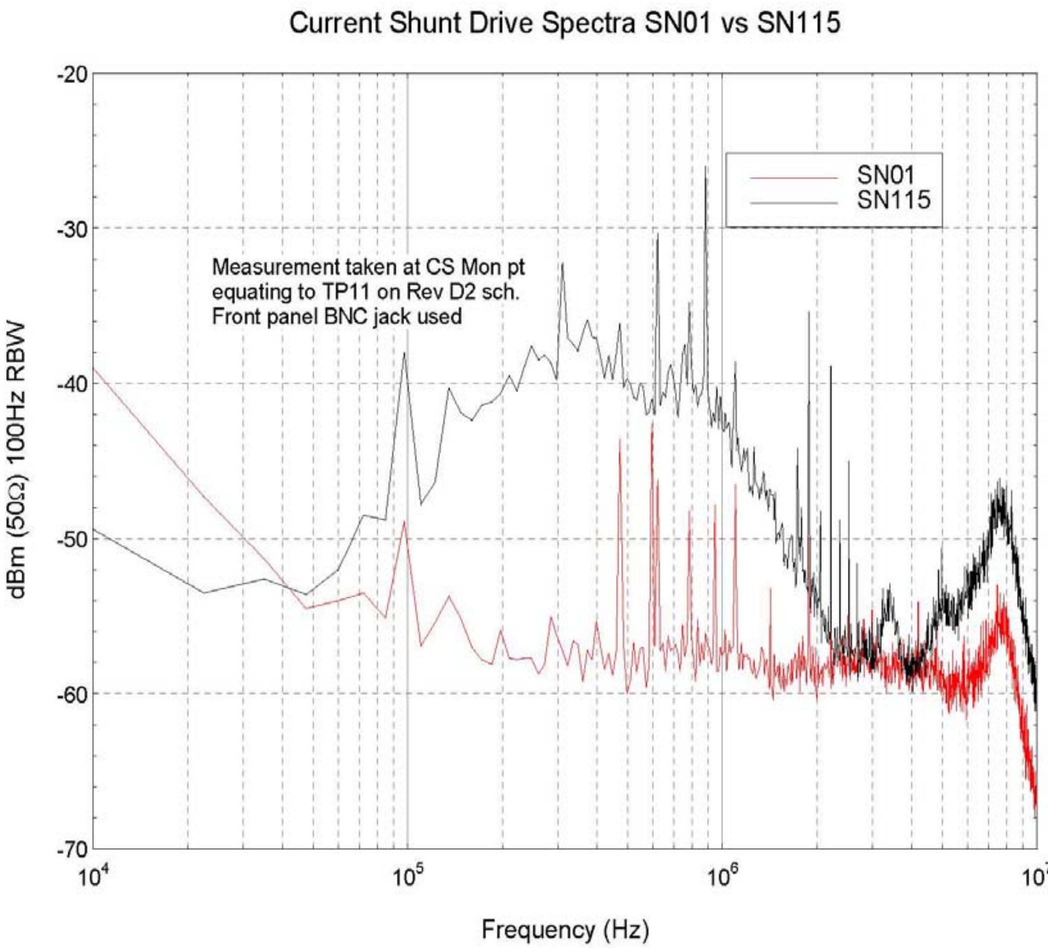


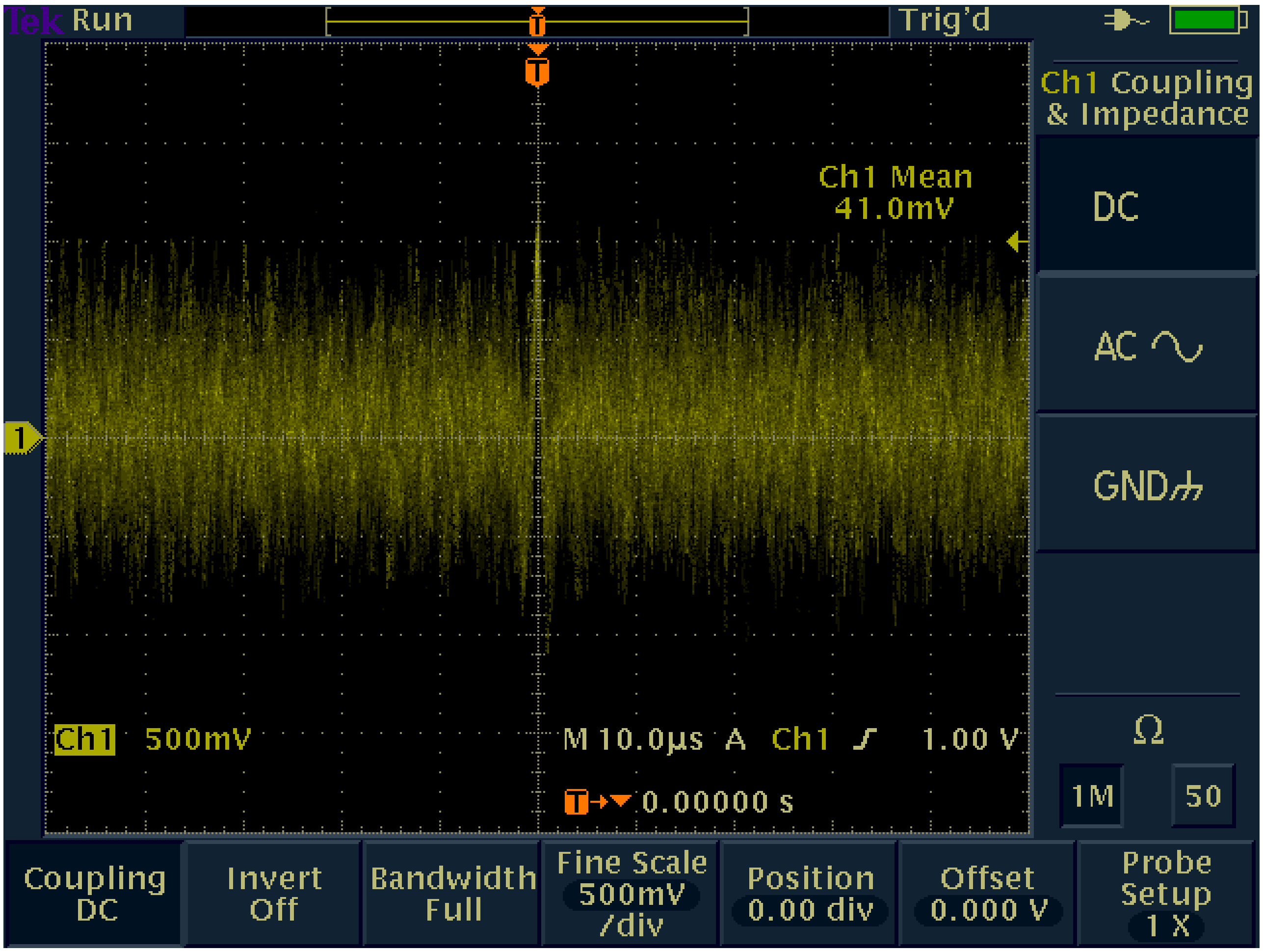
Figure 11


Current Shunt Drive Spectra SN01 vs SN115
SN01
SN115
Measurement taken at CS Mon pt
equating to TP11 on Rev D2 sch.
Front panel BNC jack used
dBm (50Ω) 100Hz RBW
-20
-30
-40
-50
-60
-70
10^4
10^5
10^6
10^7
Frequency (Hz)

3.4.7 Current Shunt Drive Time Series

Figure 12 shows a screen shot from an oscilloscope taken at the Current Shunt Drive monitoring BNC on SN115 ISS during normal operation.

Figure 12



4 Source Files

All original source files used for the plots contained in this report are available at:

http://www.ligo.caltech.edu/~abbott/files/iss_115.zip