LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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Test Results for Wenzel Associates Frequency Multiplier

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1 Introduction

Measurements were taken to characterize the frequency multiplying components purchased from Wenzel Associates. Measurements were taken of VSWR, harmonic feed through, back propagation of harmonic energy, voltage regulator noise, and power consumption. The testing was done at an input frequency of 24.5 MHz and unless otherwise noted, a drive level of 10dBm.

At this time, no detailed measurements were taken to check that the phase noise of the output signal matches the theoretical predictions. This largely a consequence of not having appropriate crystal sources on hand. A preliminary examination with a narrow band spectrum analyzer shows no observable unexpected phase noise.

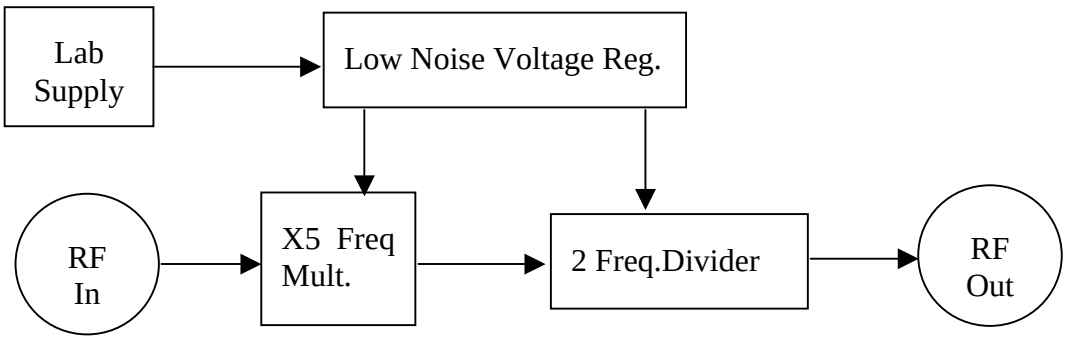
2 Measured Device Data

2.1 5X frequency multiplier – Model number LNOM-24.483-5-13-AB-AA Serial number – 6344-0520

2.2 Divide-by-two frequency divider – Model number LNFD-2-122.42-13-1-13 Serial number - 6347-0520

2.3 Low Noise Voltage Regulator - Model number LNVR-18-15-1-5 Serial number – 6349-0520

3 System Configuration



4 Low Noise Voltage Regulator

The low noise voltage regulator requires 18VDC input and supplies up to 1 amp continuous current at 15VDC. The regulator itself consumes about 50mA. When the multiplier/divider components are connected, an additional 150mA is drawn.

The voltage regulator has excellent noise reduction and ultimate noise floor. A lab supply was used to produce the required 18VDC input. The voltage noise was measured over a range of frequencies from 4Hz to ~1.5kHz for both the lab supply input and the low noise regulator output.

At 100Hz, the lab supply noise was ~200nVrms/rtHz while the regulator output noise was less than or equal to ~10nVrms/rtHz. Similar reductions in noise were seen across the measured span.

It is worthy of note that Wenzel does not supply a dedicated ground terminal for either the input, or the output of the voltage regulator module. I called them to ask why and was told that the unit is normally mounted on a metal plate that serves as a general ground and a heat sink for the regulator casing. During testing the unit did not heat up appreciably, so I assume heat sinking is only needed for higher currents.

5 Reflected Energy

In an effort to characterize spectral features that are reverse propagated from the multiplier input back to the LIGO frequency distribution system, a measurement was taken using an RF directional coupler placed inline with the input drive to the multiplier. The coupler, being a three-port device, was characterized at 24.5 MHz and is summarized in the table below.

Table 1. Mini-Circuits directional coupler model ZFDC-20-3

MEASUREMENT TAKEN (24.5MHZ)	INSERTION LOSS
Input to output	-0.14dB
Input to coupled port	-19.3dB
Output to coupled port	-67dB

The following data was taken using a spectrum analyzer and a directional coupler oriented to look at reverse propagated energy originating from the input port of the X5 multiplier stage. The incident drive was at 24.5 MHz and +10dBm. The spectrum analyzer readings are corrected for the –19.3dB loss in the directional coupler.

Table 2. Reverse propagated energy from the X5 multiplier.

FREQUENCY	SPECTRUM ANALYZER READING
24.5 MHz	-18.7dBm
49 MHz	-28.7dBm
73.5 MHz	-47.7dBm

The next table of data shows the effect of changing the 24.5 MHz RF drive level from its nominal +10dBm to +8dBm and +12dBm. It's clear that a proper RF match only occurs at the rated RF drive level (+10dBm). Furthermore, the reverse energy is purely dependent on the passive portion of the system as none of the reflected energy readings are affected by the removal of DC power to the system.

Table 3. Effects of changing RF drive level on reverse propagated energy.

FREQUENCY	SPECTRUM ANALYZER READING
24.5 MHz (+8dBm)	-7.2dBm
24.5 MHz (+12dBm)	-5.7dBm
49 MHz (+8dBm)	-29.7dBm
49 MHz (+12dBm)	-25.7dBm
73.5 MHz (+8dBm)	-28.7dBm
73.5 MHz (+12dBm)	-23.7dBm

6 Input VSWR

Measured the input VSWR of the X5 frequency multiplier stage to be less than or equal to 1.3:1. The matching to the input of the multiplier stage is highly dependent on incident RF drive level. Using the RF network analyzer (HP8753C) at my disposal, I was only able to get to an input drive level of ~8.5dBm, therefore the actual input VSWR is probably better than the 1.3:1.

7 Output Harmonic Content

The following table shows the magnitude of various relevant multiples of the input frequency while the system is being driven at 25 MHz and +10dBm (nominal conditions). These data were taken using an HP Portable RF spectrum analyzer.

Table 4. Output Harmonic Content

MEASUREMENT FREQUENCY (MHZ)	MEASURED AMPLITUDE (DBM)
12.5	-88
25	<-110
37.5	-91
50	<-110
62.5	12
75	<-110
87.5	-103
100	-98
112.5	-98

125	-47
137.5	<-110
150	<-110
162.5	-93
175	<-110
187.5	-20
250	-55
312.5	-53