LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

-LIGO-

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How many chirp-like signals are in the environmental data?
An Introduction

by

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Characterizing the PEM Data for Chirps[1]

   We are determining the "chirpiness" of the Physics Environmental Monitor (PEM) data; in particular, the seismic data is discussed here, but similar reasoning applies to the other PEM channels.   In other words, we are determining the number of false events expected to come from the seismic vibrations inducing motion into the test masses. This motion matters only to the extent that it appears like a chirp (given that inspiral wave forms are the most likely signatures). What can happen is as follows. Seismic activity that approximates a ramped sine wave moves the slab and thereby gets coupled to the test mass through the seismic isolation stack. After passing through the stack the motion may now be close enough to the chirp signature of a binary inspiral of a given mass to trigger the software to indicate a detection. If that happens, of course, a false detection occurs. We study the false detection rate assuming that the given PEM channel is the only motion inducing agent acting on the test mass. The false event rate for a channel is one benchmark for the chirpiness of the channel.

   Block Diagram 1 shows the experiment to determine the benchmark for seismic noise. We register the motion of the ground using accelerometers and seismometers.   The data from these instruments is feed to an anti-aliasing filter and then to an ADC (Analog Digital Converter). The data goes through processors and 4 km of fiber. It is then dumped into the frame builder where it is woven into a frame with other LIGO data. One can then use a piece of software called "**JD client;**" this program allows one to pull any channels one wishes and put them on a local hard drive on the CDS network. One then ftp's the data to the GC network to Homer which has a 16Gigabyte disk dedicated to data analysis. Also, a version of **GRASP** which we have modified resides on the GC network on Homer. The modified Grasp program uses the C routines to look for chirp signals in the data (through the application of **Matched Filters**). Qualitatively speaking, it looks for chirps by testing the data against a bank of binary inspiral templates. If the software finds a potential match it then does two other tests to make sure that the signal is a chirp;

   1) it does a test for any non-gaussian behavior in the noise

   2) it does a test to see if the power spectrum is really distributed according to the chirp + white noise.
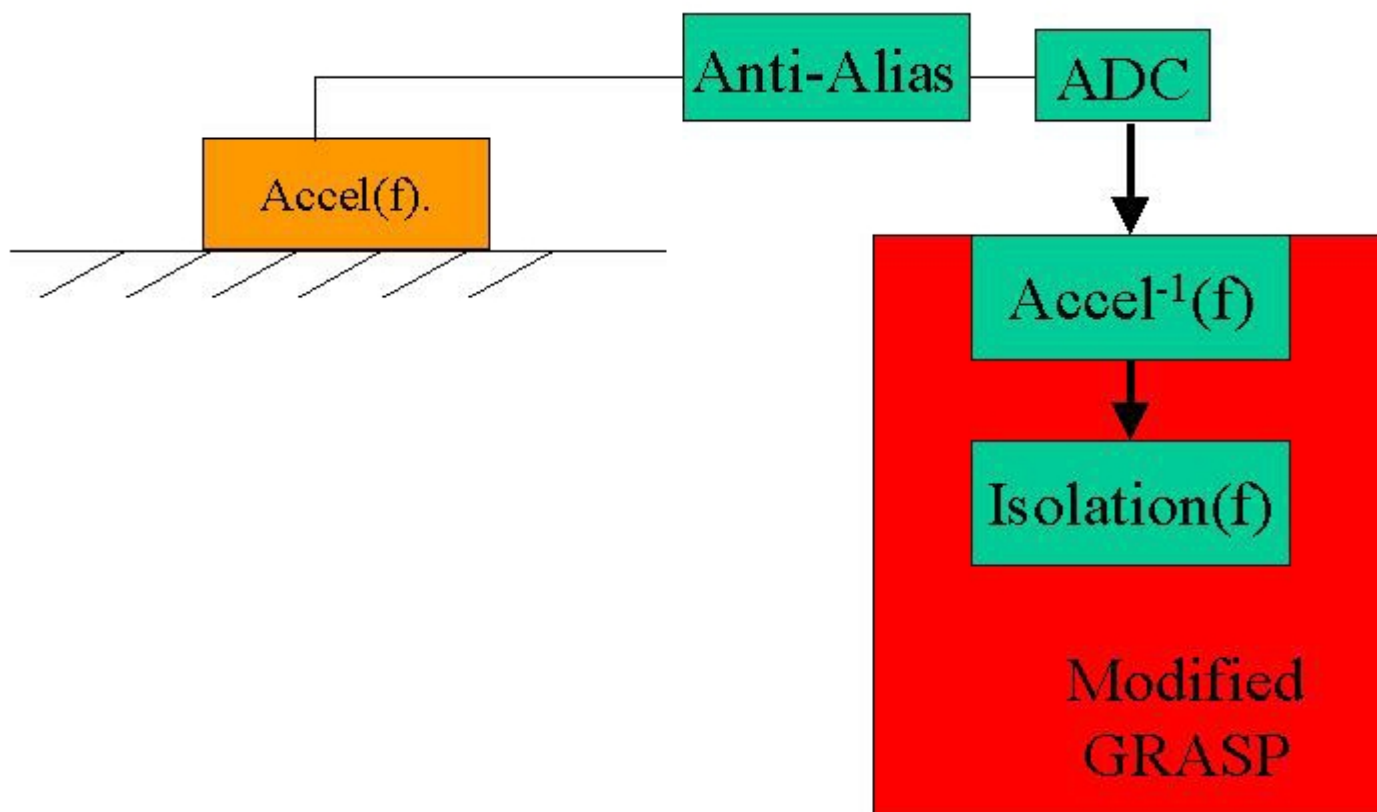
Block Diagram 1
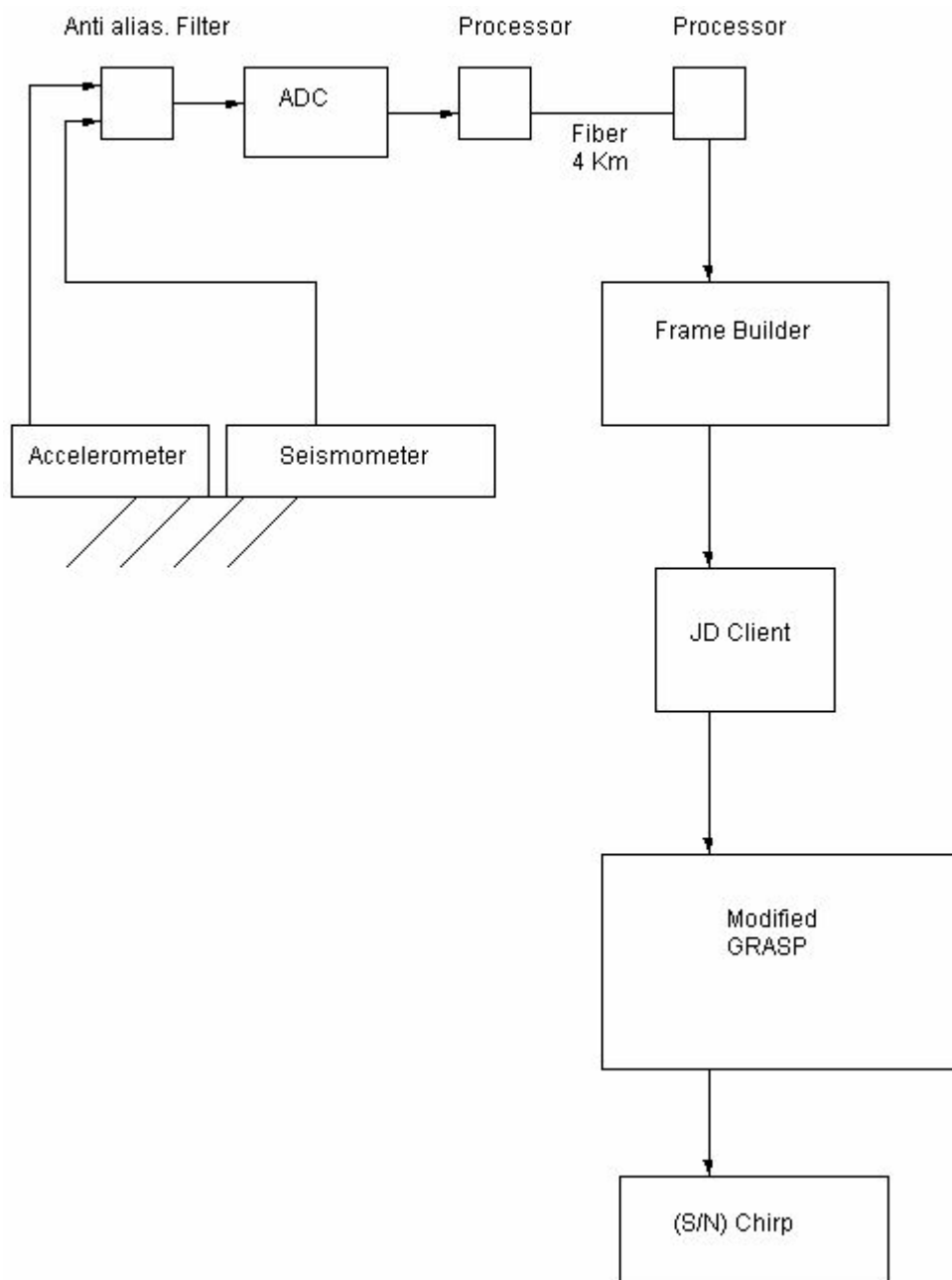
   The raw data from the instruments must be properly processed before it is checked for chirps. This filtering is done in the GRASP program and is shown in Block Diagram 2. The data from the accelerometer (or seismometer) are filtered through an inverse filter that reconstructs the initial seismic input, undoing the response of the accelerometer (or seismometer) (the filter is based on the measured accelerometer's (or seismometer's) transfer function). The data is also passed through a further filter that simulates the response of the passive isolation system of LIGO. This is a very steep low pass filter. The data then is sent to a bank of chirp templates (match filtering) for comparison with predicted chirps.
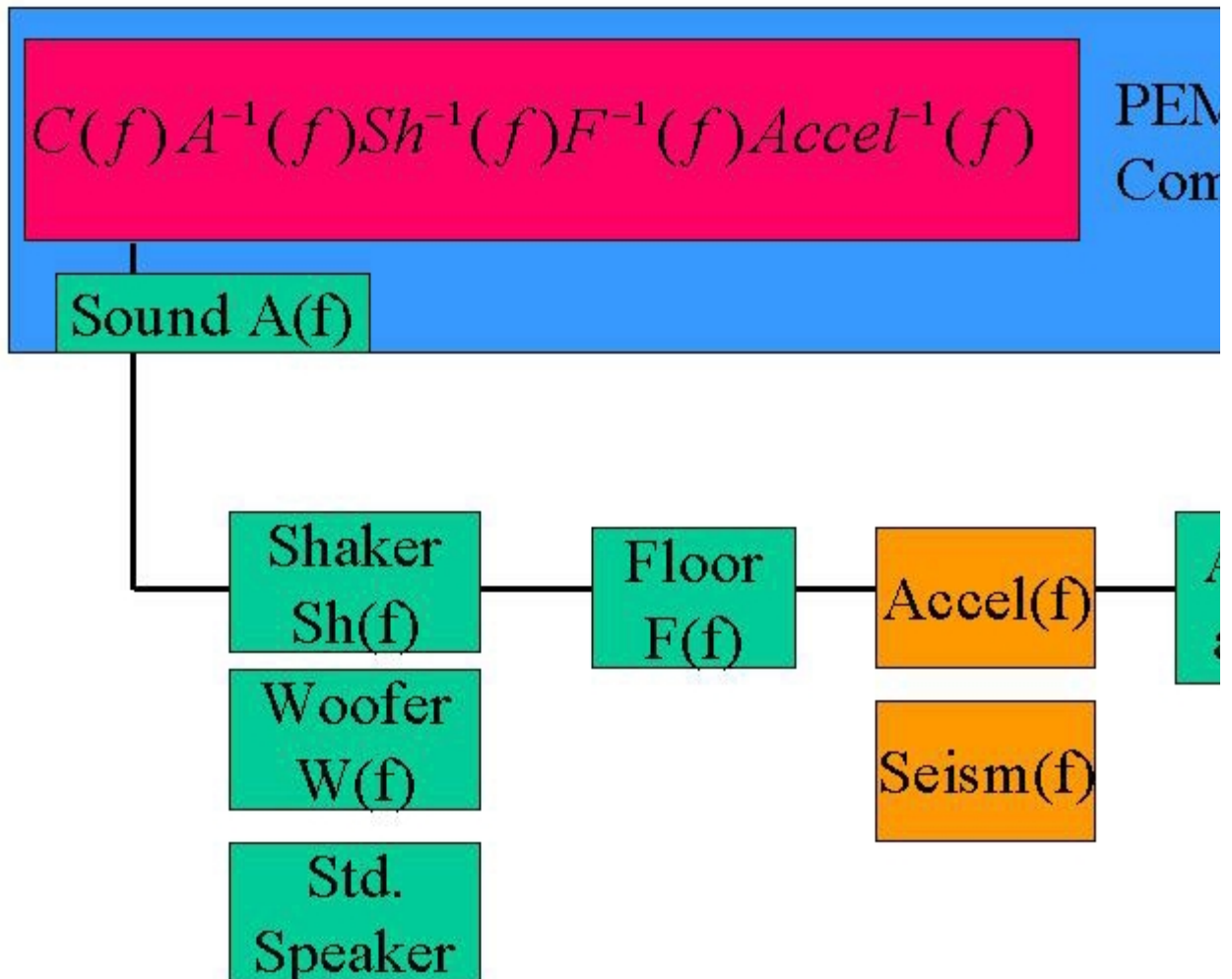
Block Diagram 2

Experimental Setup

     Before performing the experiment, we test the integrity of the entire process. **Block Diagram 3** **illustrates the most complete test of the chain. Here, we artificially inject into the ground chirps of known duration, amplitude and frequency range. Our chirp is generated using the computer via Mathematica software. The chirp that Mathematica generates is the signature of a neutron star binary inspiral wave form modified by a composite filter (i. e. the product of three particular filters) that takes into account the response of accelerometer (or seismometer), the sound card of the personal computer (used to convert the digital information of the PC into an analog signal) and the shaker (sitting on the floor in one of the end stations of the LIGO detector) that transforms the electrical signal from the PC's audio into mechanical motion that can be effectively coupled to the ground. Finally, this ground motion is sensed by the seismometer or accelerometer and put into modified GRASP. The successful detection of a chirp of the right type, verifies the entire chain from ground motion through software. (A simpler test is done for practical reasons which involves only a swept sine input to the shaker.)**

Block Diagram 3

Ground Injection

$$C(f)A^{-1}(f)Sh^{-1}(f)F^{-1}(f)Accel^{-1}(f)$$

PEM
Com

Sound A(f)

Shaker
Sh(f)

Woofer
W(f)

Std.
Speaker

Floor
F(f)

Accel(f)

Seism(f)

The schematic of LIGO's arms is illustrated in the next figure. The LIGO interferometer includes two 4 km vacuum pipe systems, roughly the south and west arms, perpendicular to each other. Inside the vacuum pipes travel laser beams that are reflected back by mirrors located at the end stations of the detector. The mirrors are suspended

through vibration isolation systems described schematically in the inset. We used the known transfer function of such isolation system to construct the appropriate filter Is(f).

Schematic of LIGO's arms
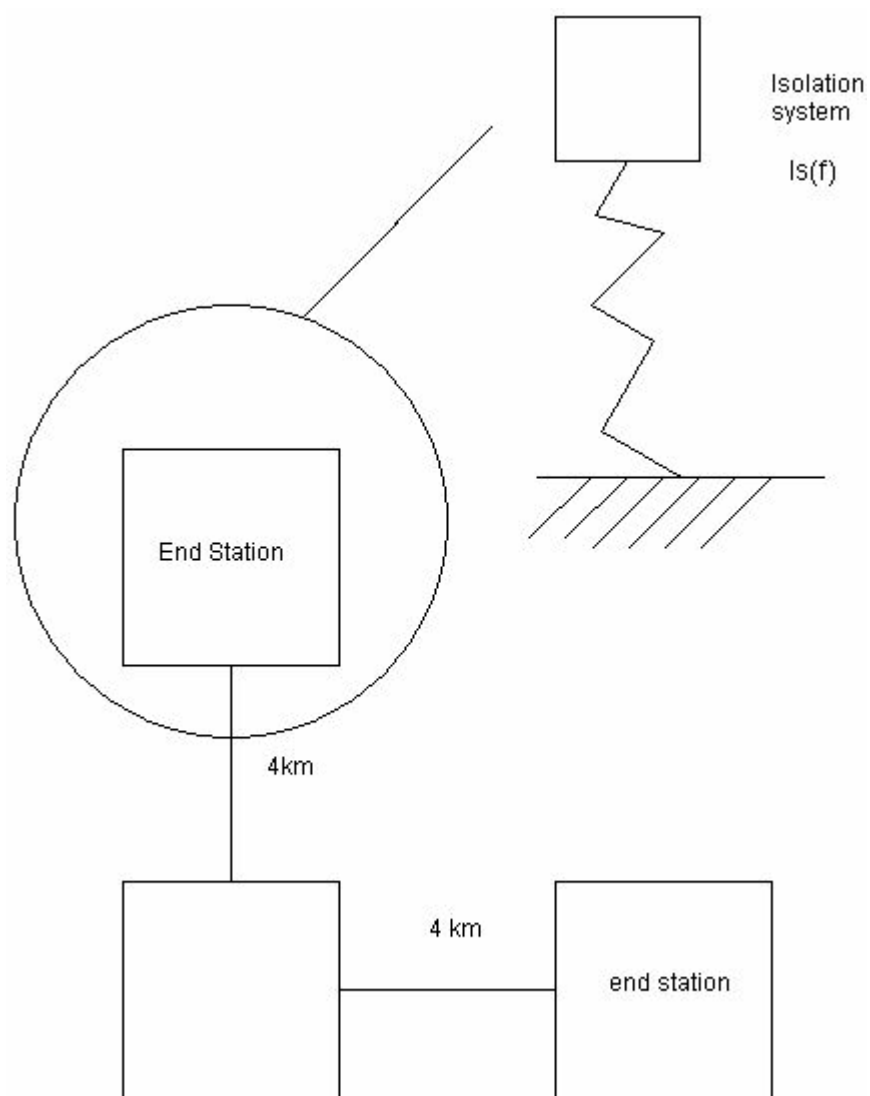
This web page is meant to be a brief summary of the project; it is not meant to and does not contain all the details and does not illustrate the many pronged nature of the project.