LSC Six-Month Progress Report

LIGO- M000083-00-M

Organization Experimental Relativity Group (ERG) of the Pennsylvania State University

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Attachment A:

Paragraph 8.A: Detector Characterization Development Group Activities:

A.1 S. Finn and S. Mukherjee made substantial progress toward completing a detailed report on the use of Kalman filters to identify and track violin modes and other stochastically excited narrow-band features in the interferometer data stream(s). The report describes the construction of the filter, its use on simulated data sets as well as the November 1994 LIGO 40M data set, and a detailed characterization of the filters performance. Partial results were described in a written version of S. Mukherjee's presentation to the 1999 Amaldi Meeting (available as gr-qc/9911098) and a final report is expected to be completed shortly.

During the period of this report S. Finn visited LHO to learn how to use the LIGO Data Monitoring Tool (DMT) and begin developing within it an implementation of the Kalman filter. During this visit S. Finn and J. Zweizig developed a general C++ class for implementing general digital filters together with a container class that provides the filter with multiple inputs and gives it a mechanism for returning multiple outputs. Additionally, the first specific component required to implement the Kalman filter --- a quadrature amplitude modulation filter --- was implemented and tested in this framework. The filter class and container class and the QAM filter are now part of the DMT and were included in the latest release of the DMT software.

A.2 S. Finn and M. Huq completed work on the use of use of signal identification techniques for regressing environmental artifacts from the instrument data stream. The focus of this study was on 60 Hz line contamination of the November 1994 LIGO 40M data stream. Partial results were provided in their contribution to the 1999 Amaldi Meeting conference proceedings (available as gr-qc/9911001). A detailed technical report is currently being written. The matlab codes used in this exercise are being polished and will be made available to the collaboration shortly.

A.3 S. Mohanty has completed a technical report on his new time-frequency stationarity test. The most important new property of this test is its independence from the noise statistics when computing the false alarm rate for a given threshold. This will be of use when the data is uncharacterized to begin with. A report on the test was placed on the gr-qc archive (gr-qc/9910027) and a paper describing it has been submitted to Phys. Rev. D. Several talks were delivered reporting the work during its development (LSC meeting, Stanford, 1999; Bursts'99 workshop at AEI, Golm, 1999; GWDAW'99, Rome, 1999). The test has been applied to the Caltech 40m data and preliminary results were reported at GWDAW'99. The test was also applied to Seismic data recorded at LHO and provided by Prof. Fred Raab. A report on that was submitted to Prof. Raab. A technical problem with the installation of the Data Monitoring Tool at Penn State has delayed the implementation of this test in the DMT. While this problem is being resolved, the test is being coded in ROOT using some of the functions/classes developed by the DMT team.

A.4 S. Finn and S. Gupta have used the Kalman filtering routines developed by the S. Finn and S. Mukherjee, and the powerline regression routines developed by S. Finn and M. Huq, to investigate how "cleaning" the November 1994 LIGO 40M data stream by removing these artifacts changes the statistical character of the data stream. In one investigation they investigated the rate of excess noise events when the data is run through a set of matched filters for black hole inspirals, finding a substantial reduction in the number of excess events. In another investigation they characterized the statistical character of the data stream in terms of its kurtosis, finding that the character of the data became more Gaussian following the removal of these artifacts. One more investigation, on the change in the detection efficiency, is underway, following which their results will be written-up in a technical report.

A.5 S. Finn completed work on the first release of the software tool SimData, which accepts a detector design and, from it, generates time series of indefinite length and with the statistical characteristics of detector noise. The first release to the collaboration took place as scheduled on 1 November 1999. The purpose of this tool is to provide a source of data whose signal and noise content are exactly known for use in validating data analysis pipelines. The first version of SimData generates Gaussian noise arising from the superposition of Laser shot and radiation pressure noise, and thermal noise arising in the mirror substrates and their suspensions. A seismic noise module, contributed by Daw (MIT) will be added in the second release following implementation of whitening filters. Later versions will add the ability to inject signals and transient noise bursts into the time series and to generate non-Gaussian noise. SimData was developed in cooperation with the LIGO Lab E2E group, which will be taking over development and integrating it into the E2E framework following its next release. The SimData program is maintained at
<http://gravity.phys.psu.edu/~lsf/SimData>

A.6 Extensive work was done on this during visits to the LIGO Hanford Observatory during 4-10 September'99, 11-29 October'99 and 11-18 January'00. It was made obvious that there is an urgent need for a systematic procedure that adapts the suspensions controllers to the imperfections of the positioning of the optics and the different sensitivities of the local sensors. More importantly, the "tuning" of the coil-magnet actuators to produce pure forces and torques as intended became clearly important when the locking of the 2km arm cavity was impeded among other things, by coupling of forces to angles.

In September, a teleconference was organized by Dennis Coyne based on the experience with controllers mostly by G. Gonzalez, E. Black (LIGO-Caltech) and others. We decided a "procedure" for tuning the controllers needed to be investigated (since there were several proposed), tried out and written up in a way that can be applied systematically to all suspensions. In October, G. Gonzalez found out a procedure to tune the controllers' "sensing matrix", which integrated all the previous experience and explained several seemingly contradictory previous results (A Technical Document is in preparation, a draft has been circulated). During this period, and using the mentioned procedure for the etuning matrix, important diagnostics could be done on the suspensions, which proves the mirrors are moving according to the suspension models that were used, although they also suggest a larger than expected tilt and rotation of the seismic isolation stacks. We also gained valuable information on the seismic motion on top of the stacks.

In January, more work was done on the controllers procedure, this time focused on the "actuation matrix". G. Gonzalez discovered that it will be impossible to avoid pitching the masses during lock acquisition if the length inputs produce pure forces; or alternatively if pitching is avoided during lock acquisition, then there is a coupling of length into angle at higher frequencies, like the stack resonances. We are studying the resolution of this problem, but it poses a concern to be studied for new controllers and/or suspensions. A team was formed with Mark Barton (LIGO-Caltech) to write up the ultimate tuning procedure as an official LIGO installation step. Many difficulties were found during the stay in January, but the work should be finished in a visit planned in Feb 16-20. An important side issue of this work is the extensive use of the Global Diagnostic Tool systems, which makes the work possible from the Control Room, with minimal hardware changes needed in the Vacuum Areas.

G. Gonzalez participated actively also in a new study team for a new version of the suspension cnotrollers. In particular, G. Gonzalez studied the possible importance of side into angle coupling, and of local damping pitch loop gain at the microseismic peak frequency.

A.7 The University of Western Ontario group has submitted a proposal to fund their work on data mining in the LIGO 40M data set; however, there is no progress to report here.

B: Other LIGO I Activitites

B.1 The Mode Cleaner was commissioned in October. In September, G. Gonzalez and Hugh Radkins (LIGO-LHO) set up the portable Data Acquisition system to acquire long stretches of data of the mode cleaner signals, along with seismometers. This was used to diagnose the Mode Cleaner length control signal. G. Gonzalez and N. Mavalvala set up an optical lever to tune the actuators in one of the optics. G. Gonzalez also worked on the calibration of the local sensors, as well as in the tuning of the local sensors of the suspensions.

B.2 There was some interaction with LATEch, and we agreed with Dr. Greenwood to look together with programs developed in PSU to data taken in LLO by his group. More interaction happened with Robert Schoffield about gravitational gradients and other issues in environmental monitoring, while G. Gonzalez was visiting LHO. G. Gonzalez provided R. Schoffield with programs to calculate velocity of waves deduced from their correlation.

B.3 Extensive work was done on this issue, and a paper is in preparation. From the data taken inside the Vacuum Areas, it is seen that only the frequency region below 3 Hz can be characterized as produced by isotropic seismic noise, while the more important 3-30 Hz region is more likely produced by local noise sources.

B.4 The LIGO/LSC Noise Characterization/Coincidence Analysis Project has evolved into the LIGO/TAMA Coincidence Analysis Project, which has only just begun. S. Finn, S. Mohanty and S. Mukherjee are participating in this program, which is in its planning stages.

B.5 and B.6 S. Finn is coordinating a small team of LSC members (ANU, UTB, PSU) in the development of the Data Conditioning API for the LDAS system. This work is in close cooperation with the LDAS team. The first articles have been delivered to the LDAS Team: a digital lock-in demodulator (S. Finn/PSU) and a summary statistics generator (J. Romano/UTB). In progress are routines to do linear filtering and digital resampling (S. Finn/PSU), power spectral density estimation (J. Romano/UTB) and discrete Fourier transforms (ANU).

B.7 S. Finn, S. Gupta, M. Huq and S. Mukherjee and produced new versions of the November 1994 LIGO 40M data set which have the violin mode and power line artifacts removed. These new data sets are currently in the form of netCDF files, which can be read by a number of data analysis engines. Work is in progress to convert these new versions of the data sets to FRAME format.

Attachment B:

1. Cross Coupling Issues: Gabriela Gonzalez, Mark Beilby, and Aran Glancy will continue work on experiment measuring cross coupling issues related to mechanical configuration of a double pendulum plus vertical blades.

An important part of this experiment is a 3-D "shaker" that will allow us to measure transfer functions from the top of the suspension. A lot of work has been doneon the characterization of the shaker, which turned out to have multiple resonances and a complex response. This is about to be completed, and we will now be able to begin making measurements.

2. Local Damping Systems / Performance: G. Gonzalez, M. Beilby, Robert Huber, and Laura Markowitz will design and begin an experiment to compare performance of different local damping systems (point to point vs. modal damping).

R. Huber and M. Beilby have developed a systematic procedure to calibrate local sensors ands coil/magnet actuators (we are using same OSEMs as in the LIGO-MIT PNI experiment). We are now ready to start tests with a modal damping system.

3. LIGO II: G. Gonzalez will participate in LIGO II design exercise. G. Gonzalez is integrating her research plan with the GEO Reference Suspension Design for LIGO II. G. Gonzalez is also maintaining the LSC Suspensions and Seismic Isolation Web page, at http://fiji.nirvana.phys.psu.edu/~swg/.

4. S. Finn aided in the preparation of the LIGO II White Paper, preparing and verifying source rate and intensity estimates for compact binary coalescence and stochastic signals in the LIGO II detector. He also continued development of a software tool that accepts an interferometer design and returns a series of estimates of its ability to detect different sources. This tool, which has been developed in cooperation with LIGO Lab and LSC personnel, is the repository for the detector noise model ``science reach'' figures of merit that the members of the LSC Technical Working Groups have agreed to use in comparing interferometer designs and configurations. A new and extended version of this program was developed during this last reporting period. The new version has a stochastic signal benchmark as well as improved thermal, shot and radiation pressure noise models. The current version of the program is available to the collaboration at <http://gravity.phys.psu.edu/~lsf/Benchmarks>.

Other Noteworthy Activities:

S. Finn was asked to serve on the LSC Software Coordination Committee, which is charged with completing LSC software standard and placing it under configuration control, coordinating the LIGO/LSC scientific software development effort, creating a controlled software repository, establishing that LSC contributed code is consistent with the LIGO/LSC Specification and Style Guide, organizing end to end tests and the mock data challenges, and operating as the LIGO/LSC software change control board. He has been participating in the work of this committee since its inception in October 1999.

S. Finn and A. Lazzarini are representing the LSC and the LIGO Lab on the GWIC Joint Data Analysis "task force", which is investigating the technical issues associated with joint analysis of data from the several worldwide gravitational wave detectors.