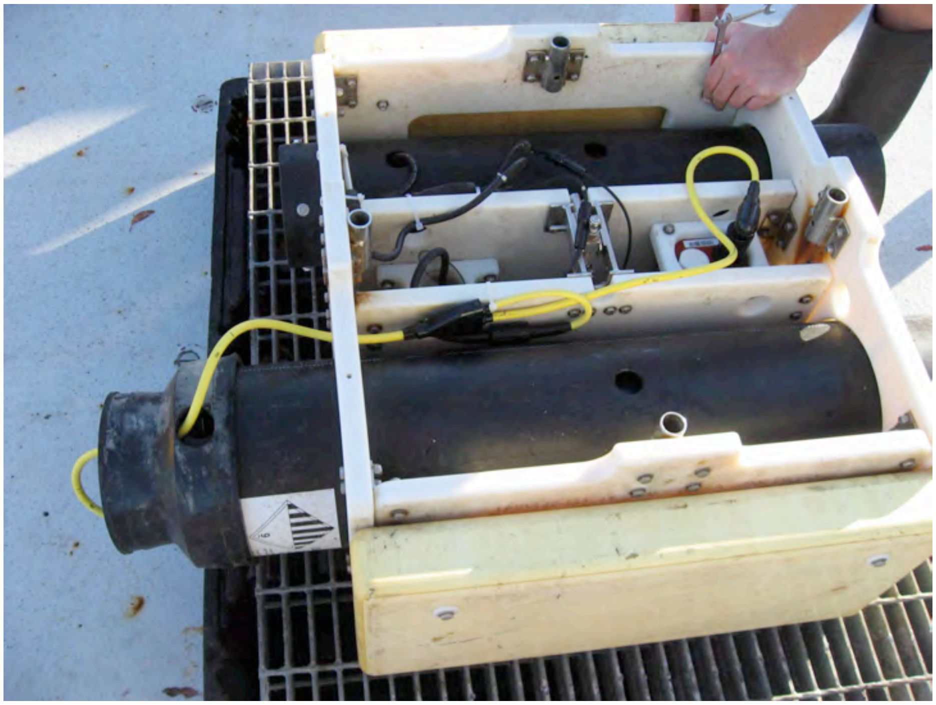
Instrument construction and testing

The most recent modification to the Long-Period fleet is a syntactic-only floatation design. This mod was required toward the deep deployment of the Forsyth et al. deployment in the NW Pacific (described below). Deployment depth are in excess of 6 km for over a year-long duration. Similar deployments off Hawaii (i.e. PLUME) saw a series of catastrophic glass ball floatation implosions, thus there was concern of the added risk invovled in these deployments. Using a stackable float design, and minimal modification to the existing LP frame, a subset of the SIO fleet is now outfitted with a more robust, long-term design solution for deep deployments. We expect all future instrument construction and upgrades to exclusively use a syntactic-only design.

Considerable instrument testing was undertaken in 2010. A few unidentified noise sources in data were identified from various field programs. Most notable were a ~6 Hz sinusoidal reverberation that was periodically present in data streams. Investigation into this noise source has shown that it is also observed on non-SIO instrumentation, suggesting that could be a "natural" environmental noise source. If instrument specific, it would also appear as if the reverberate noise is "triggered" by natural phenomenon. A detailed report of ongoing noise testing is included in the file "Append_A-Noise_Profile_Testing.pdf". This report was distributed and discussed during the users group meeting of the EPOBS Workshop held in September 25th-28th at Snowbird, Utah.

Results were verified by a longer duration "follow-up" cruise in the end of 2010, which confirmed the susceptibility of existing cable design to induce reverberation. Subsequently, all sensor cables in the active-source fleet have been replaced, which has shown to alleviate the issue. Investigations and refinements will continue if further issues arise.



LC4x4 on the deck of the *R/V Sproul* before deployment during a September test cruise. An array of LC4x4 units in various configurations was deployed simultaneously to refine instrument design characteristics. Shown is the new sensor cable with twisted-shielded wires.

I. Noise Profile Summary

The noise can be described as a parasitic resonance intermittently appearing and disappearing during the course of a deployment. The signal is emergent at the leading end, perfectly sinusoidal in the middle, and decaying at the trailing end. A consistent characteristic of the resonance is at least two of the inertial channels coming into phase upon emergence as seen in figure 1.

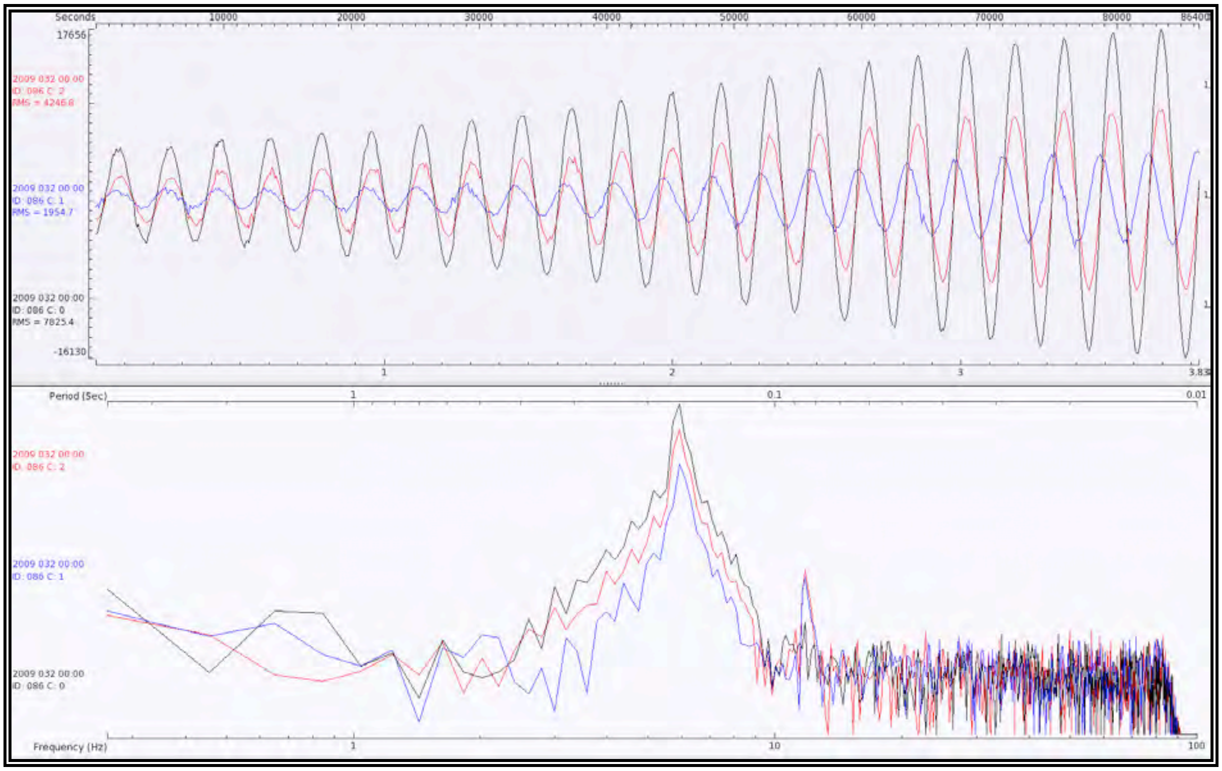


Figure 1: Resonant noise emergent characteristic showing the X and Vertical components in phase, with the Y component leading by 90 degrees. The time series axis is in seconds. The frequency axis is in Hz.

The episodic nature of onset and decay suggests an environmental catalyst. If purely electronic in origin, the expected resonance would be continuous and discrete in the noise spectrum. This is supported by the inability to recreate resonance in the laboratory or during tests at Pinyon Flat Observatory. Since the XYZ geophone components are orthogonal, the probability that an environmental signal alone could excite all components so closely in phase and with such high fidelity is low. As such, the sinusoidal character of the signal does imply a system natural frequency resonance near 6 Hz. This interpretation is supported through a series of field and laboratory tests (described in Section II).

II. Experimental Attempts at Noise Isolation

Attempts at isolation and recreation of the resonance have included the systematic tests over the past 2-years. Configuration, electronic, and whole system tests are summarized below with the observed results indicated:

Initial At-Sea Testing:

Test:	Result:
Removal of the flag	***No change***
Removal of radio antenna	***No change***
Wrapping the entire instrument in shrink-wrap to change the form factor incident to current flow	***No change***
Testing with varying anchor types	***No change***
Pre-tensioning the floatation to the frame to reduce mechanical play	***No change***

Electronic Testing in Lab:

Test:	Result:
Collection of 6 months of continuous data from a group of sea scan clocks	***Clock as a noise source not readily identified***
Electronic noise isolation of compact flash write frequency	***Fundamental write interval causes discrete 6.349 Hz signal in the self noise spectrum (with higher octaves)***
Analysis of electronics for magnetic and electric fields generated by the power distribution board-	***No noise source identified***
Analysis of digitizer self noise	***No noise source identified***
Detailed noise analysis of Crystal/Cirrus sigma-deltas	***No noise source identified***
Isolation of A2D board with shorted inputs	***No noise source identified***
Noise isolation by removal of test resistors	***No noise source identified***
Attempts at noise suppression by removal of the Mux	***No noise source identified***
Attempted noise suppression by removal of power to Hydrophone pre-amp	***No noise source identified***
Noise suppression by separation of power supply to reference	***No noise source identified***
Removal of reference-input tied to ground through 10 ohm resistor	***No noise source identified***
Removal of all gain from the system at varying sample rates	***No noise source identified***

Refined Testing:

Test:	Result:
De-coupling of the sensor from the instrument frame (no hydrophone)	***Observed reduction in magnitude***
Isolation of L28 data collection (no hydrophone)	***Observed reduction in magnitude, (occasional absence of resonance)***
Changing the type of cable connecting the sensor to the logger	***Observed reduction in magnitude***
Forensic dissection of used signal cable	***Salt water intrusion found, corrosion of copper leads***
Separation of XY and Z components to mitigate possible magnetic coupling	***No change***
Force feedback testing of magnetic coupling between the sensor x,y,z components	***Inconclusive***
Land-based data collection at Pinion Flat Observatory	***No noise source identified***
Electrical testing of signal cable	S***ignificant cross talk between leads was found due to lack of shielding between signal pairs***
Cable re-design to include twisted shielded pairs and a more robust jacket	***No observed resonance (multiple instrument configurations)***

Results of the controlled experiments suggest resistive coupling within the signal cable as a primary contributor to observed resonance. The cable is susceptible to a hydrostatic pressure effect in that the individual wire insulation is compressed, reducing the effective isolation resistance, and exacerbating crosstalk between components. The hydrophone power leads are housed within the same cable as the signal leads. The hydrophone has its own internal pre-amp, which can set up a parasitic feed-back loop within the system. Though tests are limited, an instrument array with varied configurations deployed at 1200m depth reveal that the sub set of instruments with a new shielded cable design exhibit no resonant noise.

Table 2 shows a summary of archival cruise data as related to the presence of episodic 6-6.5Hz resonant noise.

Holbrook (carib.)	**stock**	**stock**	**L28 xyz + hyd**	**~112 Hz**	**stock 4x4, A2D filter error**	**stock**	**n/a**
Holbrook 2	**stock**	**stock**	**L28 xyz +**	**200 Hz**	**stock 4x4**	**stock**	**~6.4 Hz**

Table 2: Summary of archival cruise data analyzed for episodic 6-6.5 Hz resonance

The episodic noise is observed in all data sets through 3 generations of digitizers, and two generations of sensors. The common links between the generations of instruments are the SeaScan clock, the instrument frame and floatation, the signal cables, and possibly the A2D chipset core.

The one anomaly where the noise was absent was the Holbrook et al. cruise in the Caribbean Sea. On that particular experiment, the digitizer was programmed with incorrect A2D filter settings the result of which was an odd sample rate as well as an odd compact flash write frequency, suggesting the compact flash write frequency to be one of the catalysts of the resonance.

Interestingly, the resonant noise amplitude seems to be reduced by a factor of 10 in deployments or completely absent where the hydrophone was not used.

III. Current Results and Hypothesis:

Our hypothesis is that the parasitic resonant signal results from a combination of an environmental and electronic catalyst. Though electronic noise has been isolated at 6.349 Hz, in self-noise testing it is observed at extremely low amplitudes relative to the digitizer noise floor. To date, lab tests have not been able to reproduce the same resonance observed in the waveform during sea floor deployments.

It was initially thought that the lab here at SIO was an inherently noisy site and the resonance was buried within the background signal. However, the Pinion Observatory experiments showed a background noise comparable to that of a typical moderate-depth deployment and the absence of resonance.

Continuing work:

1. Isolation of signal leads within the cable to twisted shielded pairs
2. Separation of the hydrophone to a separate cable and connector.
3. Further testing of the Geospace sensors
4. Pressure testing of new cable design.
5. Further analysis of archival cruise data.
6. Reproduction of at sea controlled experiment with new cable set.
7. Collection of data from one sensor using two digitizers.
8. Testing of a newly designed A2D board with the Texas Instruments chip set.

frame	floatation	sensors	sample rate	digitizer	cables	resonant f	ampl.
shrink wrap	stock	L28 xyz+hyd	200Hz	stock	stock	~6.4 Hz	~11 - 22
stock	tensioned/dampened	L28 xyz+hyd	200Hz	stock	stock	~6.4 Hz	~11 - 22
stock	stock	L28 xyz+hyd	50Hz	stock	stock	~6.4 Hz	~11 - 22
stock	stock	L28 xyz+hyd	1kHz	stock	stock	~6.4 Hz	~11 - 22
stock	no flag	L28 xyz+hyd	200Hz	stock	stock	~6.4 Hz	~11 - 22
stock	no radio antenna	L28 xyz+hyd	200Hz	stock	stock	~6.4 Hz	~11 - 22
stock	stock	n/a	200Hz	self noise (shorted)	n/a	6.349 Hz + octaves	n/a
stock	stock	n/a	200Hz	self noise (630 ohm)	n/a	6.349 Hz + octaves	n/a
none (SIO)	none (SIO)	n/a	200Hz	self noise (shorted)	n/a	6.349 Hz + octaves	n/a
none (SIO)	none (SIO)	n/a	200Hz	self noise (630 ohm)	n/a	6.349 Hz + octaves	n/a
stock	stock	L28 yz +hyd	200Hz	stock	stock	~6.4Hz	~11 - 22
stock	stock	L28 xy, z (open channel)	200Hz	stock, open z channel	stock	~6.4 Hz	~11 - 22
stock	stock	L28 xy+z(separate)+hyd	200Hz	stock	stock w/ z separate	~6.4 Hz	~11
stock	stock	L28 xyz+hyd	200Hz	A2D filter chng.	stock	~6.4 Hz	~11
decoupling arm	decoupling arm	L28 xyz decoupled	200Hz	stock	trillium	~6.4 Hz	~4-5
decoupling arm	decoupling arm	L28 xyz decoupled	200Hz	A2D filter chng.	trillium	~6.4 Hz	~3
stock	stock	Geospace xyz+hyd	50Hz	gain = 1	trillium		
decoupling arm	decoupling arm	Geospace xyz+hyd	50Hz	gain = 1	trillium		
none (sio)	none (sio)	L28 xyz	200Hz	stock	stock		
none (sio)	none (sio)	L28 yz + hyd	200Hz	stock	stock		
none (sio)	none (sio)	L28 xyz + hyd	200Hz	stock	stock		
none (pinion)	none (pinion)	L28 xyz+hyd	200Hz	stock	stock		
none (pinion)	none (pinion)	L28 xyz	200Hz	stock	stock		
none (pinion)	none (pinion)	L28 yz + hyd	200Hz	stock	stock		
stock	stock	L28 xyz+hyd	~112Hz	wrong filter setting	stock		
stock	stock	L28 xyz+hyd	200Hz	stock	trexonics		
stock	stock	L28 xyz+hyd	200Hz	A2D filter chng.	trexonics		
stock	stock	L28 xyz+hyd	1kHz	stock	trexonics		
stock	stock	L28 xyz	200Hz	stock	stock		

color codes:	no resonance	resonance in time domain	inconclusive	discrete spikes in frequency domain