Initial Results from Metrozet TSA-100S Testing at Berkeley Seismic Laboratory

April 25, 2005

On April 5, 2005, two of Metrozet's TSA-100S triaxial seismic accelerometers were installed in the Byerly Vault at the Berkeley Seismic Laboratory (BSL). These will be recorded as part of long duration evaluation of this new sensor technology. The TSA-100S has been designed to provide lower noise, higher dynamic range, lower hysteresis and better linearity than existing strong motion accelerometers (such as the Kinemetrics EpiSensor). The TSA-100S is a +/-4 g full-scale strong motion instrument.

Initially, the sensors are deployed without any of the thermal insulation that BSL normally uses with conventional strong motion sensors. The two TSA-100S sensors were recorded using six channels of a Quanterra Q4120 data logger. The recorder is sampling at 200 Hz. This provides an output bandwidth of 80 Hz (0.8 of Nyquist). ***The self-noise (output voltage noise) from the TSA-100S is below the input noise of the Q4120.*** In order to allow accurate sensor noise measurements, therefore, Metrozet has installed a fully-differential preamplifier between the sensor and the Q4120. The initial gain of the preamplifiers is 10X. Given the sensor's basic responsivity of 5.4 Volts per g, the amplified signal has a response of ~54 Volts per g. For reference, the Q4120 has a single count weight of 2.38 micro-volts per count. **Thus, the recorded data has a scale factor of 44 nano-g per count.**

The initial measurement period has been very quiet seismically. No significant earthquakes have occurred to date. This has provided a good opportunity to measure the incoherent (self) noise in the sensors. This report summarizes the results from these measurements.

Figure 1 shows a typical data set over a 1 hour period. Even without thermal insulation, the drift of the TSA-100S sensor is quite low (under 0.25 micro g). This data includes contributions from both ambient seismic signals, as well as sensor noise. The RMS noise (ambient + sensor) is 3.18×10^{-7} gRMS over a bandwidth of 0.003 to 80 Hz. **The actual sensor noise, calculated below, is lower.** Nevertheless, the time series data indicates a dynamic range (ratio of RMS full-scale [2.828 gRMS] to this recorded noise) of better than 139 dB. **Again, this is a conservative estimate, as it includes energy from ambient seismic signals**.

Figure 2 shows the power spectral density (PSD, in gRMS per root-Hz) of the sensor output (or ambient signal, in red) as well as the calculated incoherent (self) noise (in blue). This data uses a data set that is 1310.7 seconds long (262,184 points at 200 Hz) that has been divided into 16 smaller records. The PSD data is the RMS average of each of these sixteen smaller data sets. It provides a measurement of the spectral energy over a 0.0122 Hz to 100 Hz bandwidth. In that the Q4120 applies a brickwall filter at 0.80 Nyquist, we have truncated the PSD data at 80 Hz.

Incoherent noise is measured using the simultaneous data from the two sensors, according to a standard analysis method highlighted in the literature (see *Rev. Sci. Instr.* **v69**, p.2767 (1998)). The dual sensor technique allows one to determine the actual sensor noise in the presence of background seismic signals. This incoherent noise PSD is free of the energy from actual seismic signals that are included in the time series data above. For example, one sees clearly the microseismic noise peak in the ambient data. Because this is detected with high phase coherence by both sensors, it does not contribute to the sensor noise PSD.

Figure 3 shows a clearer plot of the incoherent noise alone. This matches the expected noise of the TSA-100S very closely. For example, the dynamic range at 1 Hz (in 1Hz bandwidth) is greater than 165 dB. This is nearly 3 times better than any +/- 4g seismic accelerometer. For reference the Kinematics EpiSensor has a specification of only 156 dB. Over a 0.1 Hz to 80 Hz bandwidth, integrated noise is 2.4×10^{-7} gRMS and the dynamic range is greater than 141 dB.

The incoherent noise is similar on each of the other sensor axes.

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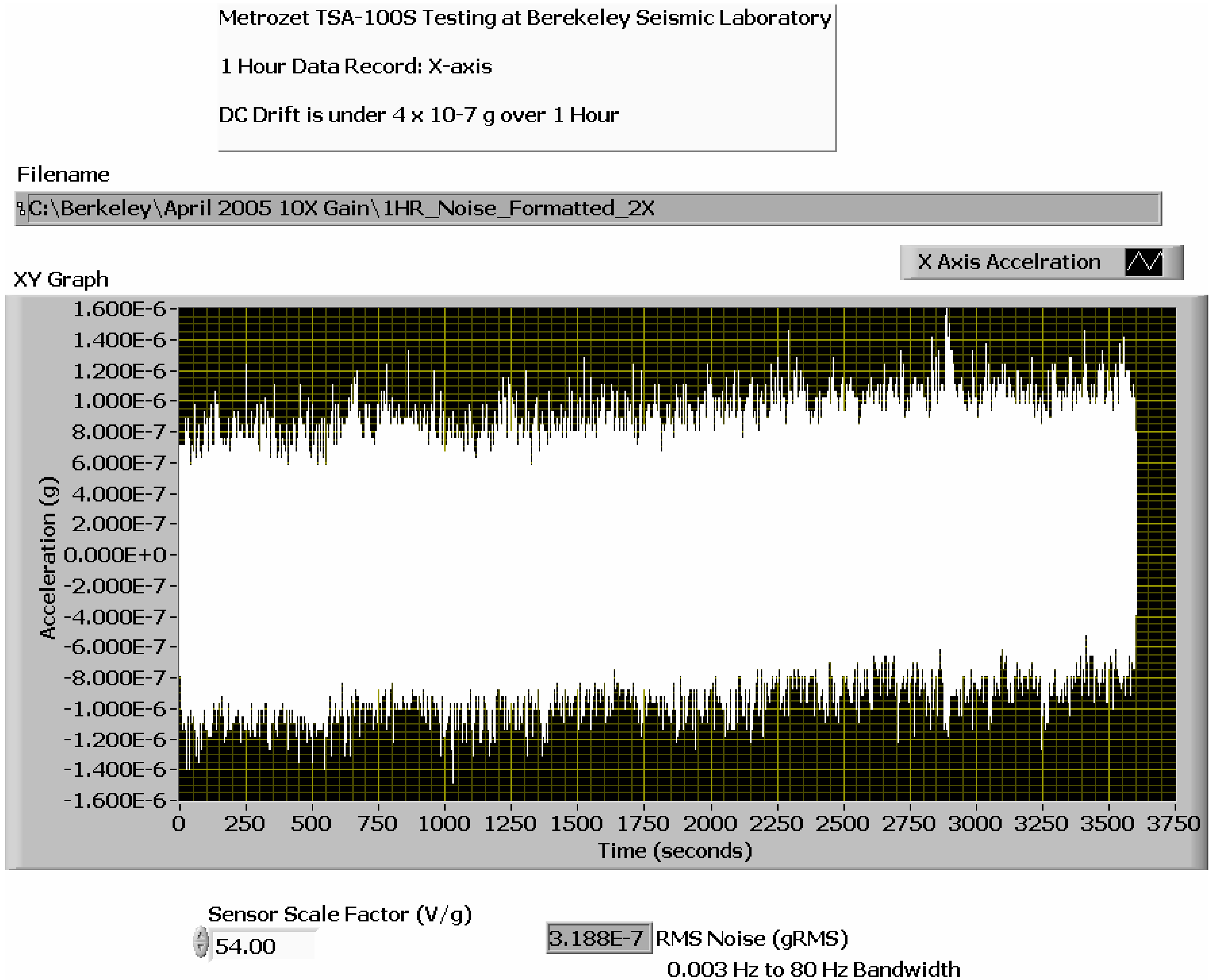

Figure 1. X-Axis Data over 1 Hour. The data bandwidth is 80 Hz. The TSA-100S is placed on the seismic pier with no thermal insulation. The long-term drift is ~0.25 micro-g over a 1 hour period.

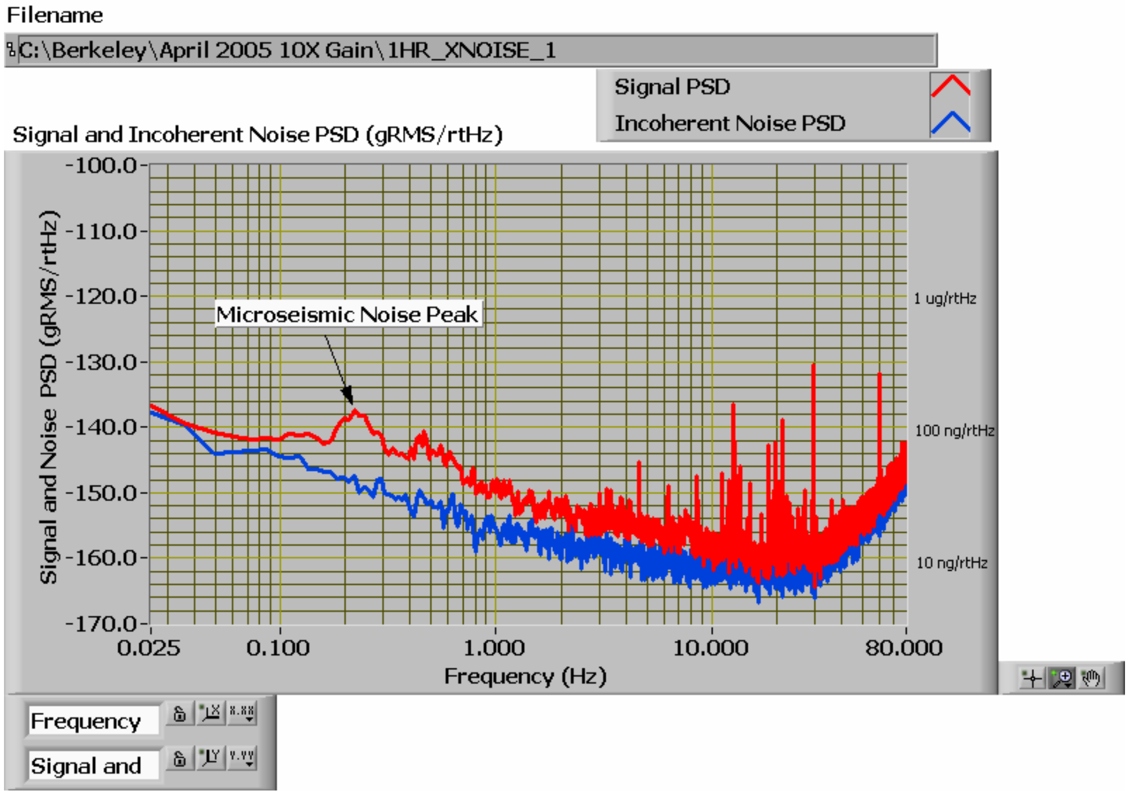

Figure 2. Plot of both ambient (signal) background noise at Berkeley Seismic Lab (red), and incoherent noise (blue) for TSA-100S sensor. The microseismic noise peak is clearly seen in the ambient signal (@0.21 Hz).Incoherent noise is determined using a dual-sensor technique.

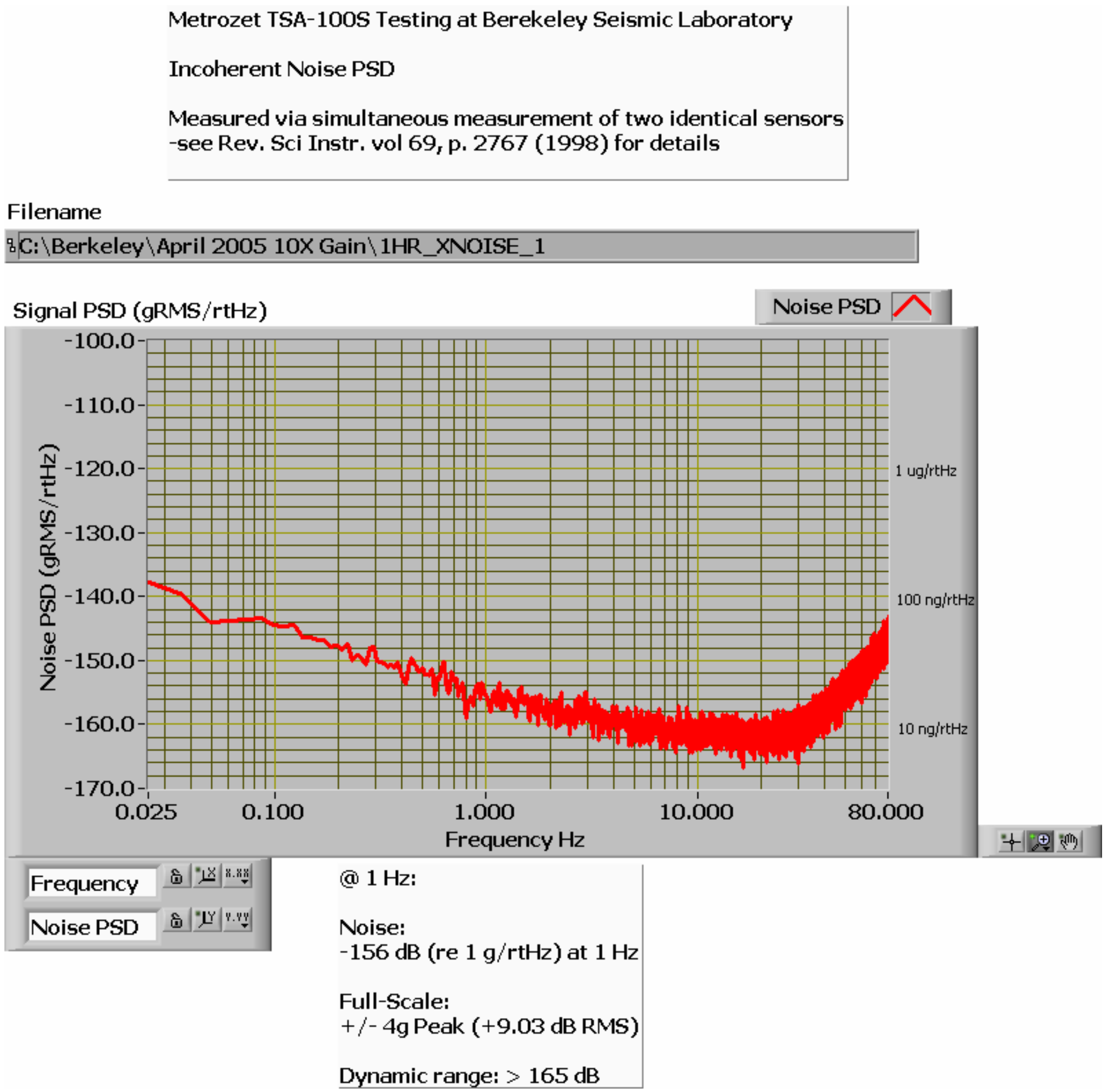

Figure 3. Plot of incoherent noise (alone) for TSA-100S sensor. The dynamic range (ratio of 2.83 gRMS full-scale range to noise, at 1 Hz) is greater than 165 dB.