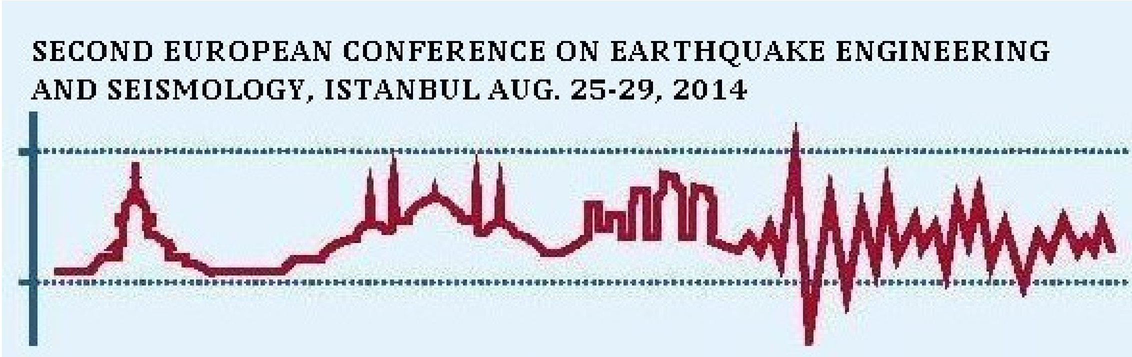

COMPARISON STUDY BETWEEN VAULT SEISMOMETERS AND A POSTHOLE SEISMOMETER

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Summary

Surface vault broadband seismometers have typically yielded good results on the vertical, but have been significantly noisier on the horizontal. There are several reasons for this issue, including inherent problems with surface tilt noise and air convection. A comparison study was undertaken between the highest performing vault seismometers and a new broadband Posthole seismometer in a down-hole installation at different depths. A spectral analysis was conducted and PSD plots were generated. We find that the burial of a seismometer results in a reduction of observed site noise that increases with depth of the seismometer, particularly on the horizontal components.

Introduction

By using the earth as a natural vault, direct burial of a posthole seismometer reduces the time and cost usually incurred when building a surface vault, which requires labour intensive infrastructure. There are distinct advantages in directly burying the seismometer because it is insulated, protected from air drafts and convection, and when installed in competent material, it is more closely coupled to the ground. In our experience, this method always yields better results than a surface vault at the same location because the posthole seismometer is more stable.

Method

A four seismometer installation was performed at Nanometrics in Kanata, Ontario, Canada, which is situated in a business park of a busy urban area. This installation includes a surface vault installation of a Trillium 120PA, a 1.2 m direct burial installation in clay of a Trillium Posthole, a 7 m cased hole installation in clay of a Trillium Posthole, and a 30 m cased hole installation in bedrock of a Trillium Posthole. A spectral analysis of ambient noise was taken for each instrument.

Results

We compare the performance of the four different installation locations. Figures 1 and 2 compare acceleration PSD plots of the site noise for each installation at low and high frequency respectively. At low frequencies the reduction of noise on the horizontal channels is immediately apparent. All three of the buried installations see at least some improvement over the vault installation. The 30 m, bedrock installation performs the best, providing vastly improved long period performance. The 7 m installation has higher tilt noise, but is still a significant improvement over the surface vault. The direct burial (1.2 m) installation performs similarly to the surface vault installation, though at frequencies between approximately 0.05 and 0.1 Hz the direct burial installation appears to offer modest improvements, particularly on the Y channel. All four installations have similar performance on the vertical channel, although the surface vault is about 3 dB noisier than the others between 0.01 and 0.001 Hz, likely because it is more exposed to temperature change.

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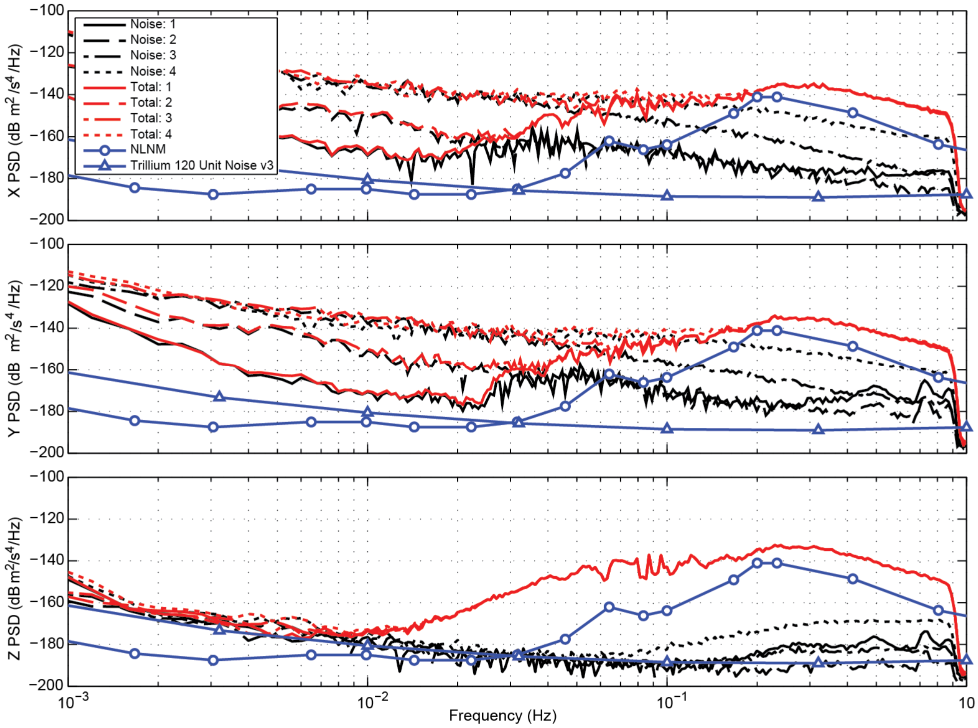

Figure 1: Low frequency acceleration PSD plots. The installation types are as follows: 1. depth of 30 m, 2. depth of 7 m, 3. buried (depth of 1.2 m), and 4. surface vault installation.

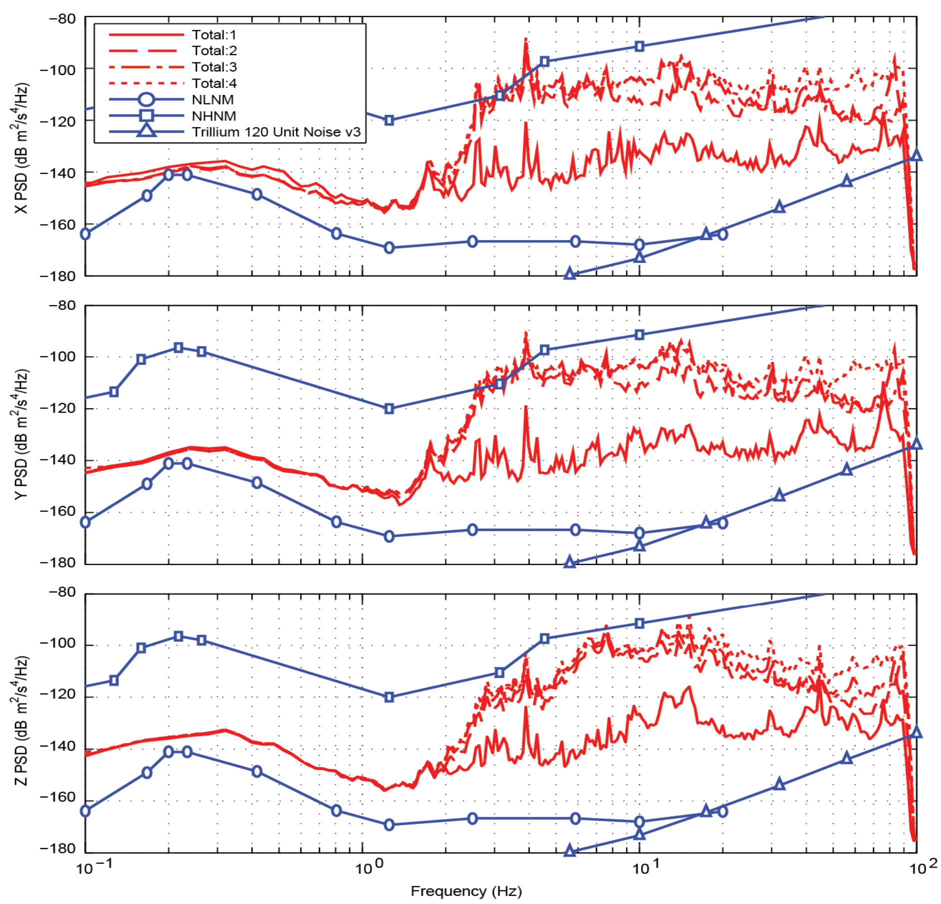

Figure 2: High frequency acceleration PSD plots. Installation depths are the same as figure 1.

At high frequencies (figure 2) the story is similar. The 30 m installation provides the greatest benefit with as much as 40 dB improvement over the surface vault installation. This is true across all three channels. The 7 m installation provides around a 5 dB improvement over the surface vault on the horizontal channel at around 10 Hz. Above approximately 50 Hz, both the direct burial and 7 m installations provide better results on both the horizontal and vertical channels. As with the low frequencies the buried seismometers provide improved performance that increases with depth when compared to a surface vault installation. For the microseismic peak between 0.2 and 1.0 Hz all four installations show similar performance.

There are several possible reasons for the improved performance. The amplitude of locally generated high frequency noise varies inversely with the velocity of the medium. By drilling to the bedrock we drill to a higher velocity medium and thus reduce the noise significantly. This explains the significantly improved performance of the 30 m burial above 2 Hz. At higher frequencies, performance improves even within the sediment layer; high frequency waves attenuate more quickly (e.g. Aki, 1980; Mitchell, 1973) and thus do not penetrate very deeply into the sediment layer. Thus the 7 m burial and even the direct burial installations show some improvement over the surface vault installation. Heterogeneities in poorly compacted sediments can also contribute to poorer quality data; this effect is mitigated through the use of buried instruments (e.g. Ata et al, 1993). Finally, the observed noise of buried seismometers is less affected by wind and temperature variations at the surface. Among other factors, these all contribute to lower site noise for buried seismometers.

Conclusions

We find that there are significant noise performance benefits associated with installing a seismometer in a down-hole environment that are not available to vault instruments. In particular, vast reductions in the observed horizontal noise are possible with buried seismometers. Posthole installations show clear advantages over surface installations including improved performance and simpler installation. Throughout all installations, the Trillium Posthole is performing to its specification of -181 dB at 0.01 Hz, as shown on the vertical channel. The posthole installation in an urban location at Nanometrics provided similar performance to a surface vault installation in a remote location. The results from this study indicate that it is now possible to get beneath the noise and keep assets secure, even in noisy urban locations.

REFERENCES

Aki, K. 1980. Scattering and attenuation of high-frequency body waves in the lithosphere. Physics of the Earth and Planetary Interiors 26: 241-243

Ata, E., Corrigan, D., Mcmechan, G., Gaiser, J. 1993. Estimation of near-surface elastic parameters using multi-component seismic data. Geophysics 58: 1017-1029

Mitchell, B. 1973. Surface Wave Attenuation and Crustal Anelasticity in Central North America. Bulletin of the Seismological Society of America 63: 1057-1071