Investigating Seismic Noise from Horizontal Components of the Nigerian Seismic Network Stations

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Research Article

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ABSTRACT

Seismic noise on the horizontal components of the Nigerian National Network of Seismographic Stations (NNNSS), comprising Awka, Ife, Nsukka, Kaduna and Toro, has been investigated using 2012 data. It was observed that the noise levels were high compared with the globally accepted Peterson noise curves for estimating station’s performance, which may likely be due to the tilt effects and other environmental and probably human factors too. For instance, in spite of the geologic and geographic locations that would have guaranteed low noise, high noise levels were observed at Toro and Kaduna stations, due to anthropogenic and self-noise from wrong instrument calibration and tilt effects, while Ife station experienced the most pronounced tilt effect. Although, geologic foundation for each site was established before siting of the five operational stations, the observed high noise levels on the horizontal component may have contributed to reducing the quality of data from the stations. This study therefore was intended to quantify the amount of noise present on the horizontal components of the stations and compare with Peterson New Global High Noise Model and New Global Low Noise Model curves, with a view to adopting better practices on installation techniques.

Keywords: NNNSS, tilt effect, noise spectral, horizontal component seismic traces.

INTRODUCTION

Seismic stations are never at rest during their routine daily recordings and they constantly contain small movements of the earth’s crust (Lay and Wallace, 1995). Noise is significantly present in all seismograms at most places in the world when the gain is tuned up and harmonic-like noise (called microseismic noise) in the frequency 0.1 - 1.0 Hz band is observed in the raw seismogram, unless obscured by a high local noise level (Alguacil and Havskov, 2002). It is a common phenomenon to observe microseismic noise dominating the seismogram; however, there is also significant seismic noise in other frequency bands which makes the specification of different noise at different frequencies desirable (Alguacil and Havskov, 2002). The noise could be from various sources ranging from cultural to instrumental and to actual earth vibrations. Basically, the origin of noise is from instrumentation and real seismic noise from the earth vibrations. Normally the instrumental noise is well below the actual earth noise (Alguacil and Havskov, 2002). But this is often difficult to see unless the person working with the data is familiar with the characteristics of the noise at a particular station. Nonetheless, it should be expressly stated that most sensors (e.g. an accelerometer at low frequencies) will exhibit some frequency band where the instrumental noise is dominating (Alguacil and Havskov, 2002).

Seismic stations usually have three sensors, one for measuring the vertical motion (Z, Positive up), north-south motion (NS, positive north) and east-west motion or the horizontal component (EW, positive east). With active sensors, the three sensors are usually combined in one box for easy orientation and installation. Instruments are the basic tools for a meaningful Seismological research, and they can only record and store meaningful data if they are properly installed. Although, the contribution of noise from the instruments is in most cases negligible, however, high noise level can be observed on the horizontal component of sensor basically from tilts (Alguacil and Havskov, 2002). One important aspect of instrumentation especially in seismic recording is calibration. The quality or otherwise, of output signal from equipment largely depends on calibration amongst other factors. Calibrating a seismograph means measuring (and sometimes adjusting) its transfer properties and expressing them as a complex frequency response or one of its mathematical equivalents (Alguacil and Havskov, 2002).
establishes knowledge of the relationship between its input (the ground motion) and its output (an electric signal), and is a prerequisite for a reconstruction of the ground motion (Wielandt, 1999).

The Centre for Geodesy and Geodynamics (CGG) has been operating the Nigerian National Network of Seismographic Stations (NNNSS) located in triangulations (Figure 1) across Nigeria.

The Awka, Kaduna, Nsukka, Ife and Toro stations are currently operational while installation of equipment at Abakiliki, Oyo, Minna, Abuja, and Ibadan stations would be completed soon. (in 2013.)

The Nigerian network of seismic stations are installed with Eetec EP 105 broad band Seismometers with the following features: Force-balanced Proprietary electrochemical sensor, 142 dB dynamic range; 2 horizontal, 1 vertical output signal; and 0.033 – 50 bandwidth.

During the installation of the seismic equipment at the NNNSS, no noise analysis was carried out and it may have been possible that bad practices in the installation procedures resulted in higher noise on the horizontal components; which may be as a result of tilt effect (Fig 2), environmental effects or human activities. (This work therefore, is aimed at making useful suggestions on better practice for the re-installation of existing seismic equipment where necessary, as well as the adoption of better installation procedures for future seismic stations' installation in Nigeria and environ).

**Sensitivity of Horizontal Seismometers to Tilts**

Seismic acceleration of the ground has the same effect on the seismic mass as an external force (Rodgers, 1968). The largest such force is gravity. It is normally cancelled by the suspension, but when the seismometer is tilted, the projection of the vector of gravity onto the axis of sensitivity changes, producing a force that is in most cases undistinguishable from a seismic signal (Fig. 1.9) (Wielandt, 1999). Undesired tilt at seismic frequencies may be caused by moving or variable surface loads such as cars, people, and atmospheric pressure (Wielandt, 1999). The resulting disturbances are a second-order effect in well-adjusted vertical seismometers but otherwise called a first-order effect (Rodgers, 1968; 1969; Alguacil and Havskov, 2002). This explains why horizontal long-period seismic...
traces are always noisier than vertical ones. Also, ground tilt caused by the atmospheric pressure is the main source of very-long-period noise on horizontal seismographs.

Figure: 2: The relative motion of the seismic mass is the same when the ground is accelerated to the left as when it is tilted to the right (Wielandt, 1999).

A short, impulsive tilt excursion is equivalent to a step-like change of ground velocity, and will therefore cause a long-period transient in a horizontal broadband seismometer (Rodgers, 1968; 1969). For periodic signals, the apparent horizontal displacement associated with a given tilt increases with the square of the period (Rodgers 1968; 1969).

Besides tilting the ground, the continuously fluctuating barometric pressure also affect seismometers (Wielandt, 1999). While it is always worthwhile to protect vertical long-period seismometers from changes of the barometric pressure, it has often been found that horizontal long-period seismometers are less sensitive to barometric noise when they are not hermetically sealed. This, however, may cause other problems such as corrosion (Wielandt, 1999).

Another important factor that disturbs the equilibrium between gravity and the spring force in a vertical seismometer is temperature changes. Although thermally compensated alloys are available for springs, a self-compensated spring does not make compensated seismometer (Wielandt, 1999). The geometry of the whole suspension changes with temperature; the seismometer must therefore be compensated as a whole. Long-term (seasonal) changes of temperature do not interfere with the seismic signal (except when they cause convection in the vault) but may drive the seismic mass out of its operating range (Wielandt, 1999). Broadband seismometers are to some degree sensitive to magnetic fields since all thermally compensated spring materials are slightly magnetic. This may be noticeable when the seismometers are operated in industrial areas or in the vicinity of DC-powered railway lines. Magnetic interferences are definitely suspect when the long-period noise follows a regular time table.

Peterson Noise Curves

The United States Geological Survey (USGS) low-noise model (Peterson, 1993) is a graphical and numerical representation of the lowest vertical seismic noise levels observed worldwide, and is extremely useful as a reference for the quality of a site or of an instrument. The curves of the so-called Peterson noise curves (Havscov and Alguacil, 2002) represent upper and lower bounds of a cumulative compilation of representative ground acceleration power spectral densities determined for noisy and quiet periods at 75 worldwide distributed digital stations. These Peterson curves have become the standard by which the noise level at seismic stations is evaluated (Havscov and Ottemoller, 2008). According to Havscov and Ottemoller (2008), the noise level can be considered worse or better than average depending on which filter band is used. So in order to do measurements in time domain, the noise values can only be compared if the same bandwidth of the filter is used.

DATA AND METHODOLOGY

The NNNSS generates digital seismic data that are routinely collected by staff of the Centre for Geodesy and Geodynamics (CGG). The data clearly indicate the station name, code and component, time (year: month: day: hour:
minute: second), start time in case of an event, and file/folder name and size for easy identification. Below is a typical data file recoded by Awka station on the indicated date.

2012-10-12-0100-12M.NSN__003  5/17/12 1:03pm NSN-003 file 476KB

Data were continuously recorded during 2012 for one year period. Power spectral densities computed from one hour long data segments from all the stations. SEISAN software was used to process the raw data and later obtain spectral figures that compared with Peterson New Global High Noise Model and New Global Low Noise Model curves. Spectral Analysis (Alguacil and Havskov, 2002; Havskov and Ottemoller, 2008) was used to determine noise levels on the horizontal components of each station and compared with Peterson's Noise Curves. The spectral analysis is based on the (Brune, 1970) model and various assumptions about the geometrical spreading and inelastic attenuation. With digital data, it is possible to make spectral analysis, and thereby get the noise level at all frequencies in one simple operation (Havscov and Alguacil, 2010; Chapman, 2004). The noise spectrum is represented as the noise power density acceleration.

RESULTS AND DISCUSSIONS

Figure 3 represents noise traces from Ife, Nsukka, Kaduna and Toro stations obtained using SEISAN software. Figure 4 is noise traces from the three components of Awka station using PQLII software. Figures 5-9 represent overlays of the spectral figures of the three components of the each station. The dominance of noise on the horizontal components is very visible due to tilt effects and other likely instrumental effects. It is more pronounced in the Ife and Toro stations resulting from mode of installation of seismic equipment in these stations, which needs to be looked into.

Figures 10-14 are estimated spectral curves from each station and compared with the Peterson New Global High Noise Model and New Global Low Noise Model curves. The results of the curves showed that the horizontal noise from the data used here are above the average of the Peterson noise curves. The problem with the horizontal component of Nsukka station can be observed as the average of the spectrum of the (Figure 12) is flat between 0.05-10Hz. The noise level at Nsukka is high at lower periods (<1sec) which may indicate the contribution of cultural noise or may be related to the instrument response correction.

At Kaduna station the noise level is high and the average noise level on the horizontal component is above the high noise model of Pederson at periods greater than 10sec. The high noise level at lower periods (<1sec) may indicate the contribution of cultural noise or maybe related to instrument response correction. High noise levels are also observed at lower frequencies of Toro, Kaduna and Ife stations but low on the Awka Station. The main course of higher noise on the horizontal component than the vertical component is the tilt effects. Wrong calibration file and instrumental response file may also be responsible for this phenomenon. The noise spectrum of the Horizontal component of Toro station (Figure 13) is almost outside acceptable limits between frequencies 0.316Hz and 10.0Hz, which might simply be due to a wrong calibration file; though the noise is high at lower periods below 0.15Hz which is due to the contributions from actual earth vibration.
Figure 4: Noise traces on the Z, N and E components of Awka Station

Figure 5: Overlay of 3-components of Toro station

Figure 6: Overlay of 3-components of Awka station
Figure 7: Overlay of 3-components of Nsukka station

Figure 8: Overlay of 3-components of Ife station

Figure 9: Overlay of 3-components of Kaduna station
Figure 10: Spectral figure of the Horizontal component of the Ife Station (2012-06-01-0000-00M.NSN_012)

Figure 11: Spectral figure of the Horizontal component of the Kaduna Station (2012-04-01-0000-00M.NSN_012)

Figure 12: Spectral figure of the Horizontal component of the Nsukka Station (2012-04-01-0000-00M.NSN_012)
CONCLUSION

Spectral noise analysis has been performed on the five functioning NNNSS using Seisan and PQLII software. It was observed that the noise levels in all the horizontal components of the stations are high compared to the standard Peterson's noise curves. The deviation is however not excessive to extent it will render the data useless. However, better practices in installation practices can help to boost the quality of data generated from these stations. The high noise levels were likely caused by tilt effect from atmospheric pressure or load etc. Therefore, there is need to carry out detailed noise analysis at each station on horizontal components of the stations and at longer period, say six months to one year to understand the distribution, trend, consistency or pattern of seismic noise specifically. Nonetheless, the findings as contained in this paper would go a long way to helping operators of the Nigerian Seismic Stations on better installation practices of seismic equipment to improve data quality.

This is a preliminary investigation using PQLII and SEISAN software available at the time of this work. Other software like PQLX and NOISECON could also be used in future to better understand the noise characterization on horizontal components of each station.
REFERENCES