GROUND MOTION ISSUE ON THE LARGE ACCELERATOR ALIGNMENT

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Abstract

There are many proposals of future next generation accelerator facilities in the world, those are electron-positron linear collider, very large hadron collider and muon collider. All of these colliders are very sensitive with respect to external ground motion noises. Incoherent seismic vibrations are considered among the most severe disturbances. In addition to the seismic vibrations, however, slow drift of the ground occurring like Brownian motion of rocks becomes dominant at frequency region less than seismic vibration. We present spectral and correlation characteristics of the ground motion and discuss the results with accelerators tolerances.

1 INTRODUCTION

The electron-positron collider which should provide a center of mass energy in the range of 500GeV - 1TeV with luminosity as high as 10^{33} to 10^{34} cm^{-2} sec^{-1} . The luminosity of the linear collider is given,

$$L = \frac{f_{rep} N^2}{4\pi \sigma_x^* \sigma_y^*}$$

where f_{rep} is the repetition rate of collision, N is the number of particles per bunch and, σ_x^* and σ_y^* are transverse rms sizes of the beam at the collision point. Since the linear collider has a relatively slow repetition rate, small sizes of the beam should be generated and preserved in the machine to obtain the required high luminosity. One of the most critical parameters is the extremely small vertical size of the beam at the interaction point, therefore, a proper alignment of the focusing and accelerating elements of the machine is necessary to achieve the high luminosity [1]. The small beam size results in severe tolerance requirement for machine components. Incoherent vibration and drift of the ground would destroy the straight trajectory of the carefully aligned structure and lead to luminosity losses. Then it is very important to study the characteristics of the seismic vibration and slow drifts of the ground.

2 PROPERTIES OF THE GROUND MOTION

In the frequency range f < 0.1 Hz, the measured continuous power spectrum of the ground motion can be characterized by k/f^2. This coefficient k is site dependent and changes from 1 to 10^2 um^2/Hz. The sources of the slow ground motion are atmospheric activity, change on underground water, ocean tide, earth tide, micro-earthquake and temperature variation of the surface ground etc. [2, 3]. In this frequency range, differences in geological and topographical properties take part in the block movement of underground rocks. At high frequency f > 0.1 Hz, the power spectrum is very complex and superimposed with the noises of various sorts as following:

(1) artificial noises; cooling water system, air conditioner, power supply, traffic noises, public work etc.,
(2) ocean swell around 0.2 Hz,
(3) crustal resonance around 3Hz,
(4) earthquake.

3 DESCRIPTION OF GROUND MOTION

We have to know the time and space characteristics of the ground motion, since the motion influences directly on the operation of large scale accelerators. The motion shows a random like process in all most all cases, then we can describe their average behavior in a stationary condition. The power spectrum of the random process x(t) is defined as,

$$P(f) = \lim_{T\to\infty} \frac{1}{T} \left| \int_{-T/2}^{T/2} x(t) \exp(-2\pi f t) dt \right|^2 .$$

The power spectrum gives squared dispersion,

$$\sigma^2 = \int_{-\infty}^{+\infty} P(f) df = \left\langle x^2(t) \right\rangle = \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} x^2(t) dt .$$

Since the power spectrum is real and symmetric signal, it is sufficient to consider only positive frequencies. It is useful to describe the motion between distant measuring points with a cross-spectrum,

$$P_{12}(f) = \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} x_1(t) \exp(-2\pi f t) dt \int_{-T/2}^{T/2} x_2^*(t) \exp(2\pi f t) dt$$

and a normalized cross-spectrum,

$$S_{12}(f) = \frac{P_{12}(f)}{\sqrt{P_1(f) P_2(f)}} .$$

The absolute value of this normalized cross-spectrum is coherence.

4 ACTUAL GROUND MOTION

4.1 Artificial noise region

The seismic motion usually gives complex spectrum. The spectrum is composed of smooth spectrum as k/f^n, ocean swell around 0.2 Hz, crustal resonance around 3 Hz, noises of human activity in the frequency range 1 to 100 Hz and earthquake. Figure 1 shows an example of the spectrum on the quiet granite site excepting a near busy national road. Broad peak around 80 Hz is observed in the horizontal vibration. This means that the source of vibration is near traffic noises.

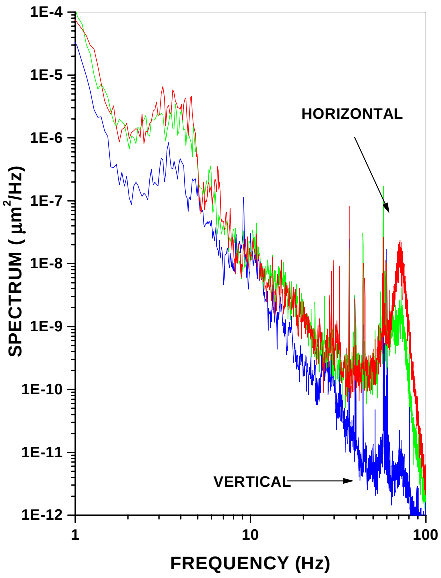

Figure 1: Ground motion in the quiet granite site.

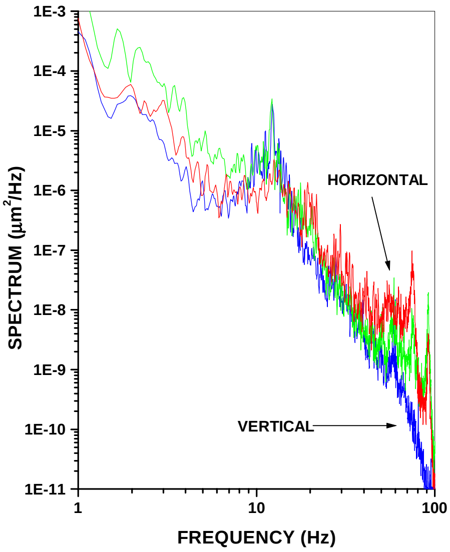

Figure 2: Ground motion in the noisy granite site.

Figure 2 shows the spectrum on the noisy granite site being in the suburbs of a big city. The spectrum of Fig. 2 shows about ten times as large as Fig. 1 in the whole frequency range. Especially, there are apparent differences between them in the frequency region 5 Hz < f < 50 Hz. Fig. 2 shows as if the artificial noises fill up the spectrum density in this region.

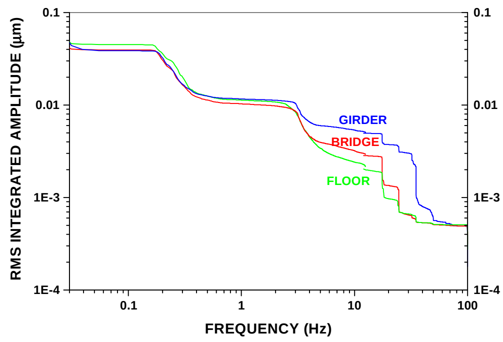

Figure 3: Integrated vertical vibration in the experimental hall of KEKB. BRIDGE is a construction on the floor and GIRDER is set up for the final focus magnet.

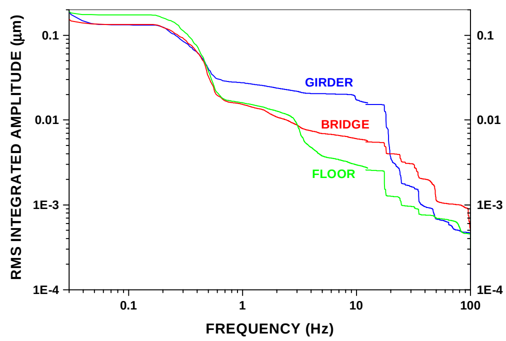

Figure 4: Horizontal vibration in the experimental hall of KEKB.

Figs. 3 and 4 show the integrated rms amplitudes of the vibration in the experimental hall of KEKB. Both figures show a clear evidence for the resonance of the girder. This resonance is induced by the mechanical vibration of accelerator facilities. It is necessary for us to work out some countermeasures for these artificial noises, as following:

(1) development of low noise facilities; low noise cooling system, low noise power supply etc.,
(2) attaching passive vibration absorber to the noise sources,
(3) site selection of low background noises.

4.2 Slow drift region

Dominant part of the ground motion at f < 0.1 Hz is inelastic motion. The earth-tide, one of the elastic motion in this frequency range, becomes cause of inelastic motion through its dissipation. One of the models describing this inelastic ground motion is *ATL* model [4, 1]. Slow relative ground motion is random and the number of discrete breaks appearing between two points is proportional to the distance and the passed time. These discrete breaks consist of random popping up/down of fragmented rocks. The popping motion of the rocks, however, are not complete random phenomena, then the two dimensional covariance function and the white noise correlation are not equivalent. The *ATL* model is one of the mathematical approximation for this covariance function. The value of *A* should be influenced dominantly by the earth properties [1, 3].

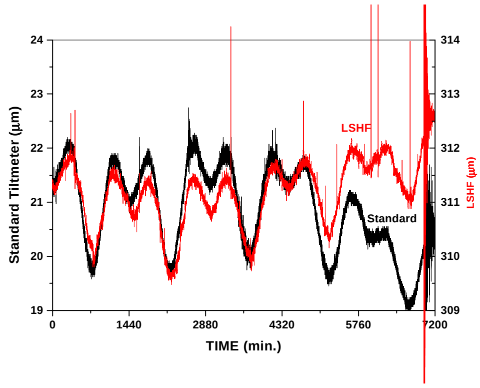

Figure 5: Ground motion in the quiet granite tunnel. The data are taken at the same position, but using different methods. Both sensors are separated by a distance 28 m.

Figure 5 is a typical result obtained in the quiet granite tunnel using two different methods. One of them is the ordinary water tube tilt-meter (Standard) and the other is the Leveling Sensor with Half Filled water (LSHF) [5]. LSHF is sensitive to the local motion though the Standard gives averaged results. A large amplitude oscillation appeared at 7,000 minutes is for a distant earthquake which characteristic frequency is about 30 mHz.

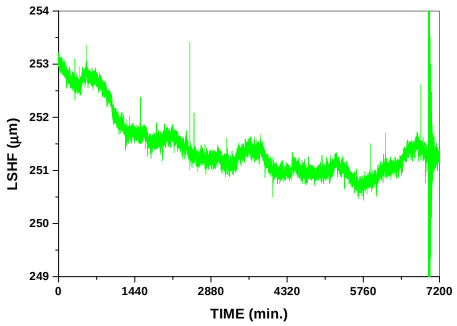

Figure 6: Subtracted signal one of the end of LSHF from the middle.

We set three LSHF's in the tunnel. Figure 5 shows the subtraction results between the both ends. Figure 6, however, shows the subtracted results one of the end LSHF from the middle one. This figure shows the related two sensors move about almost in phase. It means that the two sensors are set on the same large lump of the rock.

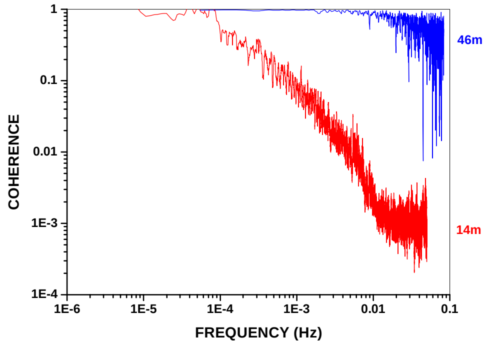

Figure 7: Different coherence on the different measuring points in the same tunnel.

Figure 7 shows the different coherence obtained in the same tunnel. One of the data shows very bad coherence though the other [1] shows very good. These results point out that the tunnel was partially broken up into fragments when tunneled, though it was excavated through integrated process. Countermeasures for the slow ground motion are as following:

(1) selection of the site; low *A* value, $A < 1\text{nm}^2/\text{m/sec}$ for a linear collider, is essential,
(2) selection of the tunneling methods; we have to avoid artificial fragmentation of the rock occurred during excavation [1],
(3) development of realignment system; active mover and beam-based compensation are essential.

5 ACKNOWLEDGMENTS

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6 REFERENCES

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