ANALYSIS OF 3RD OCTAVE BAND GROUND MOTIONS TRANSMISSION IN SYNCHROTRON RADIATION FACILITY SOLARIS

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The purpose of the measurement is to determine the levels of Ground Motion (GM) in experimental hall in synchrotron radiation facility SOLARIS. Ground motion in various areas, such as experimental hall, and a Linear Accelerator (LINAC) tunnel, are presented. Machines with high accuracy that are sensitive to ground vibrations are generally designed using crude assumptions on the dynamic properties of the floor where they are placed. This also holds for the prediction of machine accuracy in the design phase, based on expected or measured ground vibration spectra. It is well known that floor vibrations are one of the main disturbance sources for high precision equipment. Especially for equipment in the synchrotron radiation facility, like SOLARIS, but also in the other particle physics laboratory, the impact of floor vibrations on the machine accuracy is generally determining the dynamic architecture of the system. It is said that the peak around 0.3[Hz] in the GM spectra is caused by ocean waves. This phenomenon is shown by comparing GM spectra for the concrete floor in an experimental hall of SOLARIS with wave height of the ocean. Also 3rd Octave Band Analysis it was presented and corresponding Vibration Criteria were presented and discussed.

Keywords: Octave Band, Ground Motions, Synchrotron

1. Introduction

The first polish third generation light source Solaris is based on the linear accelerator and the storage ring connected with dog-leg transfer line. The linac provides the beam with maximum 600 [MeV] energy which can be injected to the storage ring and ramped up to the nominal energy 1.5 [GeV]. A storage ring layout consists of 12 novel highly integrated Double Bend Achromat (DBA) magnets designed by MAX-IV Laboratory in Sweden. One year period of the machine assembling has started in May 2014. Then the commissioning phase started and the process of fine-tuning for reaching the designed parameters is still ongoing. Most important parameters of this 1.5 [GeV] storagering are presented in Table 1. A detailed description of the machine and the layout can be found in [1–4].

Recent optimization of linear injector and storage ring allowed to reach 600 mA of injected beam at 525 [MeV] energy stored in the ring and 400 [mA] beam ramped to the nominal 1.5 [GeV] energy. Machine optics, was corrected closely to the designed values. Sufficiently stable beam along with good reproducibility of beam parameters from injection to injection allowed to start the commissioning of the first beam line — UARPES.

Table 1: Solaris Storage Ring Parameters

Parameter	**Value**
Energy	1.5 GeV
Beam current	500 mA
Circumference	96 m
Number of bending magnets	12
Main RF frequency	99.931 MHz
Number of bunches	32
Horizontal emittance (bare lattice)	6 nm rad
Tune Q_x, Q_y	11.22, 3.15
Natural chromaticity ξ_x, ξ_y	-22.96, -17.4
Corrected chromaticity ξ_x, ξ_y	+1, +1
Beam size (straight section) σ_x, σ_y	184 µm, 13 µm
Beam size (dipole) σ_x, σ_y	44 µm, 30 µm
Total lifetime	13 h

2. Instrumentation

Piezoelectric sensors use Newton's Second Law and the piezoelectric effect to measure the acceleration of a mass. A piezoelectric accelerometer contains a "seismic mass" mounted so that the force applied to the mass by movement of the housing "squeezes" or stretches a natural quartz crystal or manmade piezoelectric ceramic measuring element. The pressure on the measuring element produces an electrical charge within the material that is proportional to the force applied — the piezoelectric effect. This force, in turn, is proportional to acceleration.

IEPE Integrated Electronics Piezoelectric) sensors have built-in signal conditioning circuits having low impedance output electronics, compatible with a two-wire constant current supply providing a DC voltage bias. IEPE sensors are very popular in numerous industrial applications except those which special requirements such as static (zero [Hz]) sensing, high temperature applications, or process control applications.

Four mono-axial seismic accelerometers were used to measure the ground motion, with a sensitivity of about 1000 [mV/m/s2].The mass of each transducer is 635 [g] (PCB 393831). The usable frequency range of a sensor is from about 0.1 [Hz] up to 1/3 to 1/2 of the natural resonance frequency (700 [Hz]). In order to increase the frequency, either the stiffness should be increased or the mass decreased. Since decreasing mass also decreases sensitivity, increasing stiffness is preferable. In most cases, a combination of the two approaches is required.

The accelerometers were glued on the structure with wax. The natural frequency of an unmounted sensor is different from that of a mounted sensor, because the mounted sensor has a stiffness determined by the stiffness of the structure in which it is mounted. Attaching the sensor to a structure can lower the natural frequency by a substantial amount.

Connectors and cables are often the weak link in an instrumentation chain. The triboelectric effect is the generation of an error signal in a charge output sensor whenever its attached cable is physically moved. The only effective way to eliminate this error signal is to clamp the cable as close to the accelerometer as possible. The cables were securely fastened to the structure to minimize cable whip as well as the connector strain.

3. Results

While spectral transforms like FFT provide constant absolute bandwidth (i.e. the bins are equally spaced in terms of Hz), 1/n octave analysis provides an analysis bandwidth which is proportional to the centre of each band throughout the analysed frequency range. This is called constant relative bandwidth.

3.1 Vibration criteria for work with sensitive equipment

The VC Curves Specification define the vibration criteria which need to be met for certain types of sensitive equipment to be used in the specified area. The comparison of the data acquired from the measurement and the curves is typically done for the RMS value of velocity integrated over the 1/3 octave bands within the frequency range from 1 to 80 [Hz]. The highest VRMS over this range and calculated this way, determines the actual VC range for the tested area. Table 1 shows the velocity values which need to be met for certain vibration criteria. The same information is shown on the graph above. The ground vibration measurement is performed for all three directions (2 horizontal, 1 vertical) and the VC specification needs to be used for each one of them. Typically for high precision equipment, vertical V_{RMS} values should be below the VC-F curve, while the horizontal ones– below VC-G.

3.2 Speed RMS [µm/s per 1/3 octave band]

In the 1/n octave analysis, the signal to be analysed is split into partial signals by a digital filter bank before the vibration level is determined. The filter bank consists of several filters connected in parallel, each with a bandwidth of 1/n octave. An octave filter is a filter whose upper cut-off frequency is twice the lower cut-off frequency, whereas 3rd octave filters further subdivide each octave band into three parts and so on. This means that octave filters or 1/n octave filters don't have a constant absolute bandwidth, but a constant relative bandwidth, i.e. the frequency bands are equidistant on a logarithmic frequency scale.

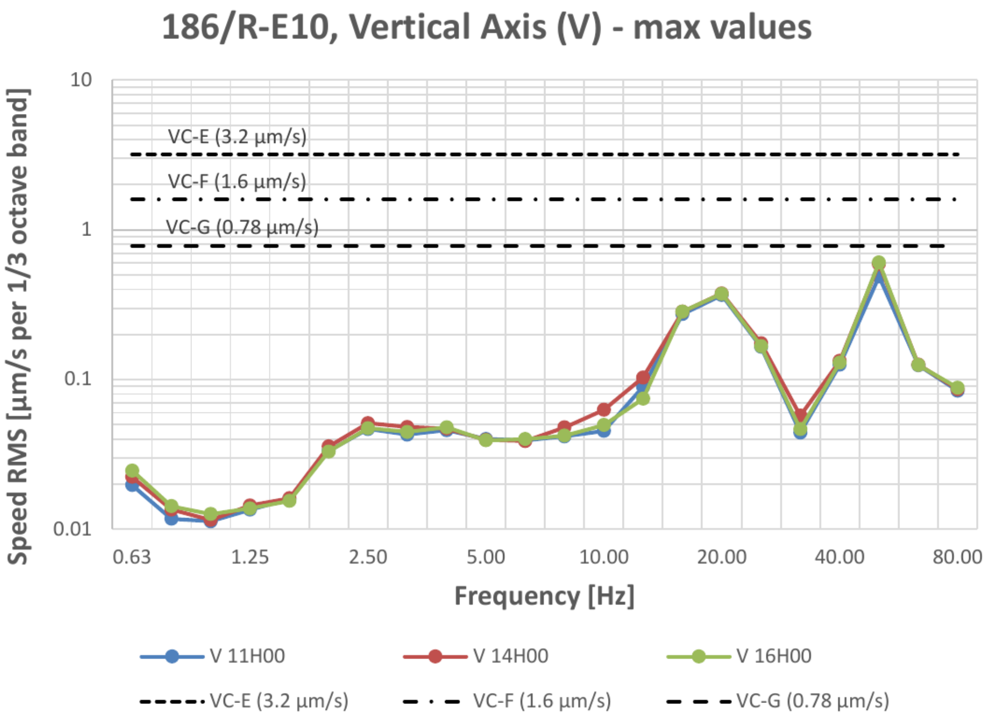

Figure 1: Speed RMS [µm/s per 1/3 octave band] - vertical axis

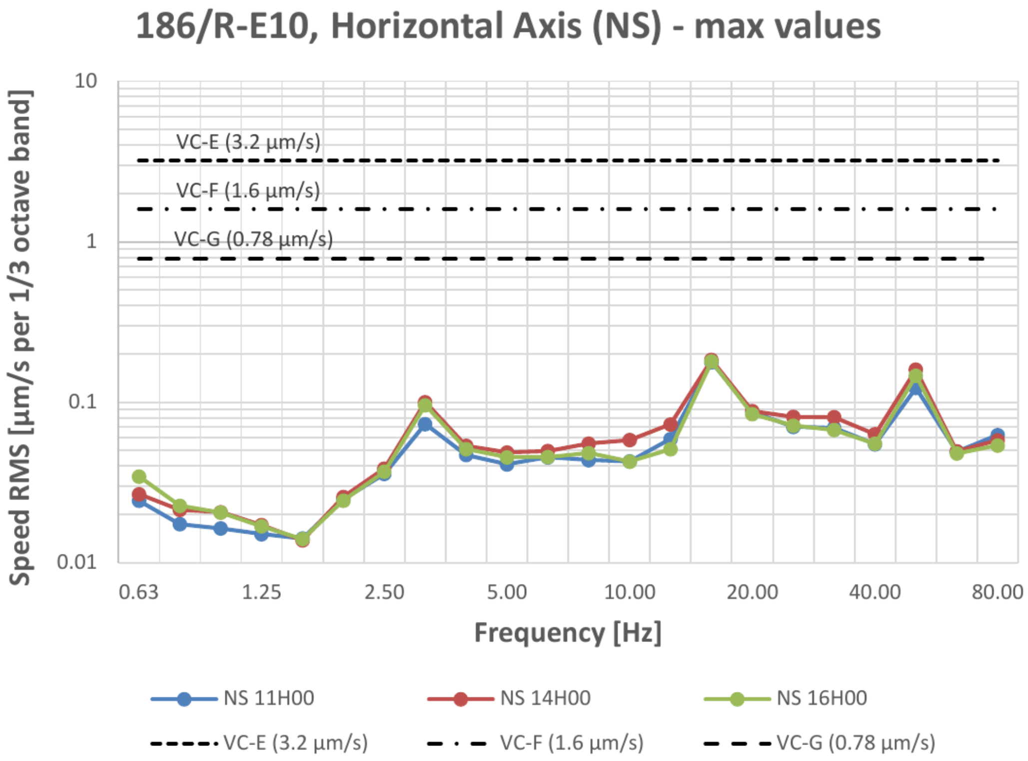

Figure 2: 3.2 Speed RMS [µm/s per 1/3 octave band] - horizontal axis NS

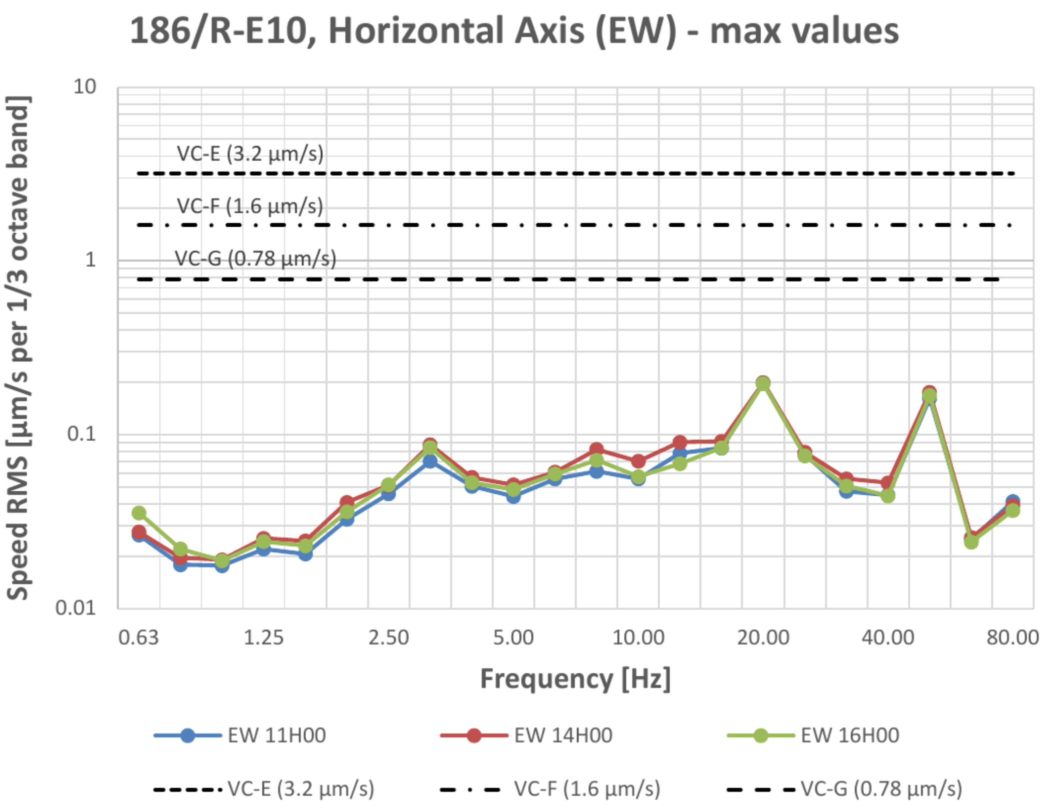

Figure 3: 3.2 Speed RMS [µm/s per 1/3 octave band] - horizontal axis EW

3.3 Evaluate the power spectral density

The first analysis was to evaluate the power spectral density for each direction of sensors and event. The ground motions at several locations measured in are plotted in (Figure 4). These locations are divided into three groups. The first group (red lines) is the synchrotron bunker, the second group (green lines) is the experimental hall and the third group (black lines) is the tunnel linac.

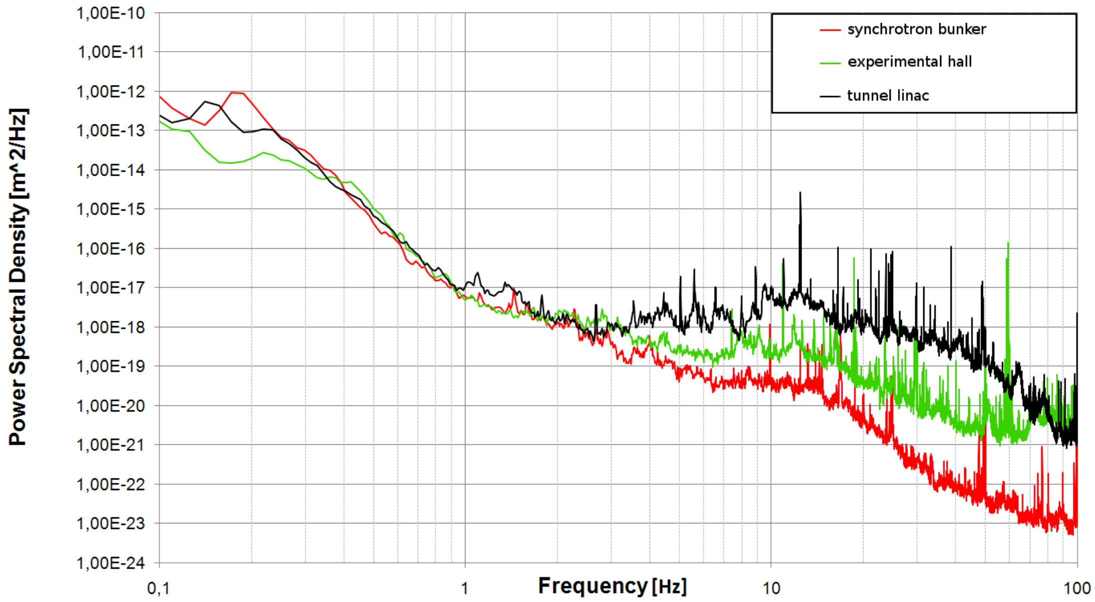

Figure 4: Power Spectrum Density

Integrated is used to sum up the total vibration of the PSD. It gives the RMS (Root Mean Square) value of the total vibration The integrated RMS ground motion in vertical direction (the average of the measurements) are show and compared with the results of similar research centres in the world. The (Table 2.) shows the results at 1 [Hz].

Table 2: Integrated RMS value at 1 [Hz]

RMS Integraded values	@1 Hz [nm]
SOLARIS	4,8
CLEX experiment	13,3
AEGIS experiment	13,0
PSI particle accelerator	11,8
CMS experiment	6,8
CesrTA particle accelerator	3,8
LSS4 Caver-SPS Accelerator	4,1
TT1 tunnel (ISR)	2,3
LHC tunnel (DCUM584)	1,9

4. Conclusions

The ground motion spectrum can be separated in two main regions. The low frequency region below about 2 [Hz] which is dominated by natural motions sources like ocean waves and earth tides, and the high frequency region above 2 [Hz] which is dominated by cultural motion sources like traffic, industry, transformers, pumps and people walking. The power spectral density graphs above clearly shows the distinction between these two regions. In the low frequency region, all locations have a similar ground motion dominated by well correlated natural motions. In higher frequencies the ground motion is dominated by the local cultural noise, and the highest ground motions occur at locations with high cultural activity.

From the vibration measurements performed in the laboratory SOLARIS and the following 3rd Octave Band Analysis in can be seen that vibration levels in the specified locations are below the VC-G curves at all times in which the measurements were performed and within the whole relevant frequency range (1-80 [Hz]). This in turn means that the specified location is adequate for the purpose of operating a high precision equipment such as a parts of detector experimental lines in question.

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