Contents

International standards for ride comfort analysis

There are a number of standards used for ride comfort analysis, they are commonly ISO 2631:1997 and Sperling Ride Index (Wz). This document deals with the more commonly used ISO 2631:1997 that is also predominant in the railway industry.

ISO 2631:1997-1 deals with generic ride comfort that can be used for roadside vehicles whereas ISO 2631:1997-4 deals with railway vehicles.

The standard requests to apply a non-symmetric filter on vibration data (for all directions X / Y / Z axis) in order to come up with a [RMS] root mean squared value (average vibration). This average vibration is then compared with standard limits that determine whether the ride was considered comfortable or not comfortable.

The filter is shaped in such a way that the highest or worst frequencies felt by the human being are weighted the most i.e. dominates the calculation of RMS; which is around 10Hz according to ISO 2631:1997-4.

ISO 2631:1997 evaluates frequency weightings for health, comfort and perception and for motion sickness.

Assumptions – Essentially, ISO 2631:1997 does not take into account vibration exposure time.

Types of motion taken to account by ISO 2631-4

Motion in a fixed-guide way vehicle is characterized by:-

a) Random translational accelerations (in all three axes) and semi-random angular accelerations (about all three axes) due to imperfections in track/wheel surfaces, track alignment errors, etc.,

b) Periodic motions due to instability problems (swaying), motions in suspension, long-wave track irregularities, periodic distances between joints, staggered track, etc.,

It is also contributed by other factors if track geometry are inherently imperfect:-

c) Quasi-static magnitudes of acceleration along both lateral and vertical axes and roll (bank) and yaw motion due to alignment and cant (super-elevation) and quasi-static magnitudes of acceleration along the longitudinal axis due to acceleration or braking of the vehicle, and

d) Sudden motions due to large imperfections in track or switches, or changes of quasi-static levels (jerk) due to changes in curve radii with or without transition curves.

Frequency spectrum expected in railway applications

Normally, the frequency range of motions expected to impact ride comfort significantly in conventional rail vehicles includes:-

0,1 Hz to 2 Hz on curve transitions (roll), 0,5 Hz to 10 Hz in the lateral and longitudinal directions, and 0,5 Hz to 20 Hz in the vertical direction.

For ultra-high-speed vehicles (250 km/h and faster) and for tilting trains, vertical accelerations in the frequency range 0,1 Hz to 0,5 Hz can occur. Such low-frequency vertical accelerations can induce kinetosis (motion sickness) – refer to ISO 2631-1:1997, annex D.

Calculation of [RMS] Root Mean Squared Vibration

RMS is a single value weighted from different frequencies perceived to be related to the human perception of discomfort. The approximate filter shape is shown as below:-

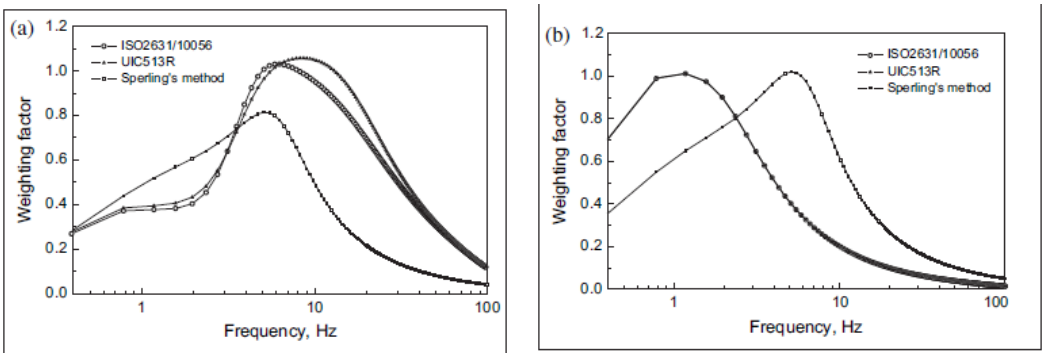


Fig. shows the frequency weight functions for different standards to get the RMS value:
(a) vertical direction and (b) lateral and longitudinal directions

Pre-filter – in accordance with ISO2631 spectrum limits, a 0.5Hz to 80Hz filter is applied to the system. For other standards such as when using the MacMinder hardware, the filter bandwidth is much tighter i.e. 0.05Hz to 20Hz.

The filter shape / parameters are different depending on which axis is concerned, the orientation of the human being and what type of analysis is required (motion sickness, perception, comfort or health).

W_b—Weighting for vertical whole-body vibration, z–axis, seated, standing or recumbent person, based on ISO 2631–4 (railway vehicles).

W_c—Weighting for horizontal whole-body vibration, x–axis, seat back, seated person, based on ISO 2631-1.

W_d—Weighting for horizontal whole-body vibration, x– or y–axis, seated, standing or recumbent person, based on ISO 2631-1.

W_e—Weighting for rotational whole-body vibration, all directions, seated person, based on ISO 2631-1.

W_f—Weighting for vertical whole-body vibration, z–axis motion sickness, seated or standing person, based on ISO 2631-1.

W_h—Weighting for hand-arm vibration, all directions, based on ISO 5349-1.

W_j—Weighting for vertical head vibration, x–axis recumbent person, based on ISO 2631-1.

W_k—Weighting for vertical whole-body vibration, z–axis seated, standing or recumbent person, based on ISO 2631-1

W_m—Weighting for whole-body vibration in buildings, all directions, based on ISO 2631-2.

Refer to the ISO standard for the Wx filter parameters.

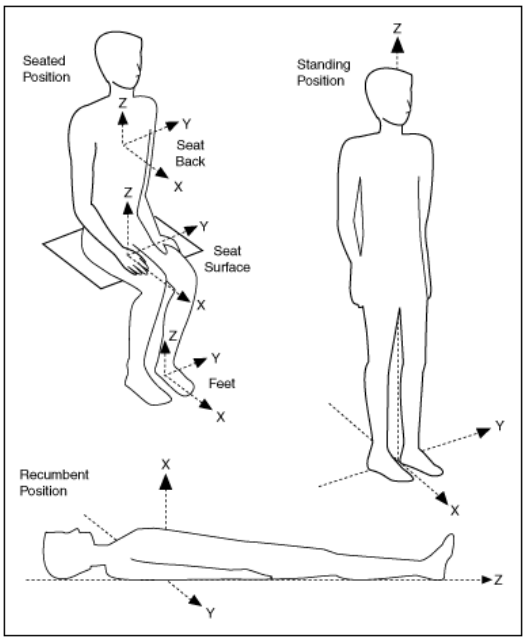


Fig. Human orientation

For the common case of a seated human being on a train, the parameters to be chosen are:-

Z axis – Wk filter

Y axis - Wb filter

X axis – Wb filter

Evaluation criteria

As per ISO-2631-1 section C.2.3,the following table gives approximate indications of likely reactions to various magnitudes of overall vibration values in public transport.

These values apply to both X / Y / Z RMS values calculated from the previous section.

r.m.s vibration level	Perception
Less than 0.315 m/s^2	Not uncomfortable
0.315 m/s^2 to 0.63 m/s^2	A little uncomfortable
0.5 m/s^2 to 1 m/s^2	Fairly uncomfortable
0.8 m/s^2 to 1.6 m/s^2	Uncomfortable
1.25 m/s^2 to 2.5 m/s^2	Very uncomfortable
Greater than 2 m/s^2	Extremely uncomfortable

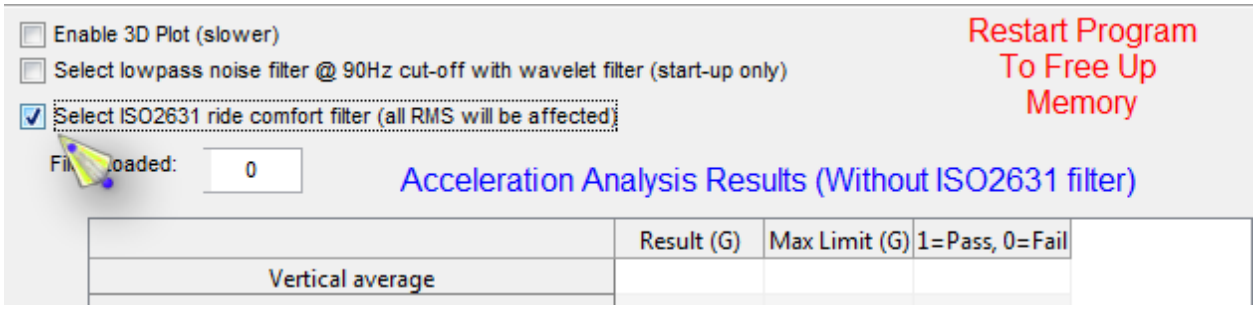
For the case when a MacMinder filter was applied, the values produces are usually around ½ in magnitude as the ISO2631 filter. To compensate for the reduction in magnitude, in Hong Kong trains, they use an acceptance criteria of 10mg and 13mg for vertical and lateral vibration respectively instead of the ISO2631 acceptance criteria.

Installing V-Sensor for Ride Comfort Measurement

- Apply double sided tape. For low vibrating structures in the order of milli G (when doing ride comfort analysis), it is recommended to apply double sided tape which results in the same results as applying adhesive. This is easier to install and take out compared with using adhesive).
- Record down the installation time in date, hours, minutes, seconds.

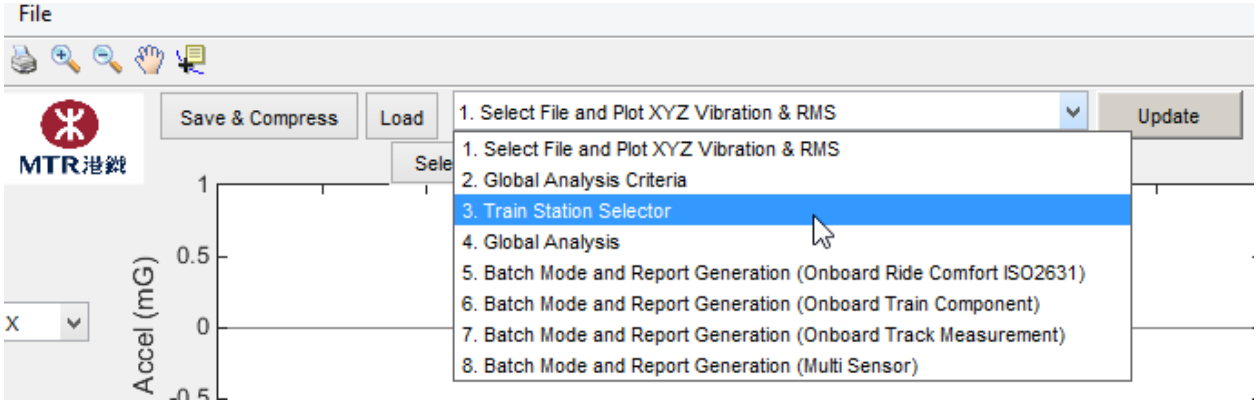
Analysis – Manual Method

1. Place a tick on the box shown below:-



2. Automatic station detection

   2.1. In the drop down menu, select option 3 Train Station Selector -> press update



   2.2. In the graph at the bottom right hand side of screen, select “select noise floor”

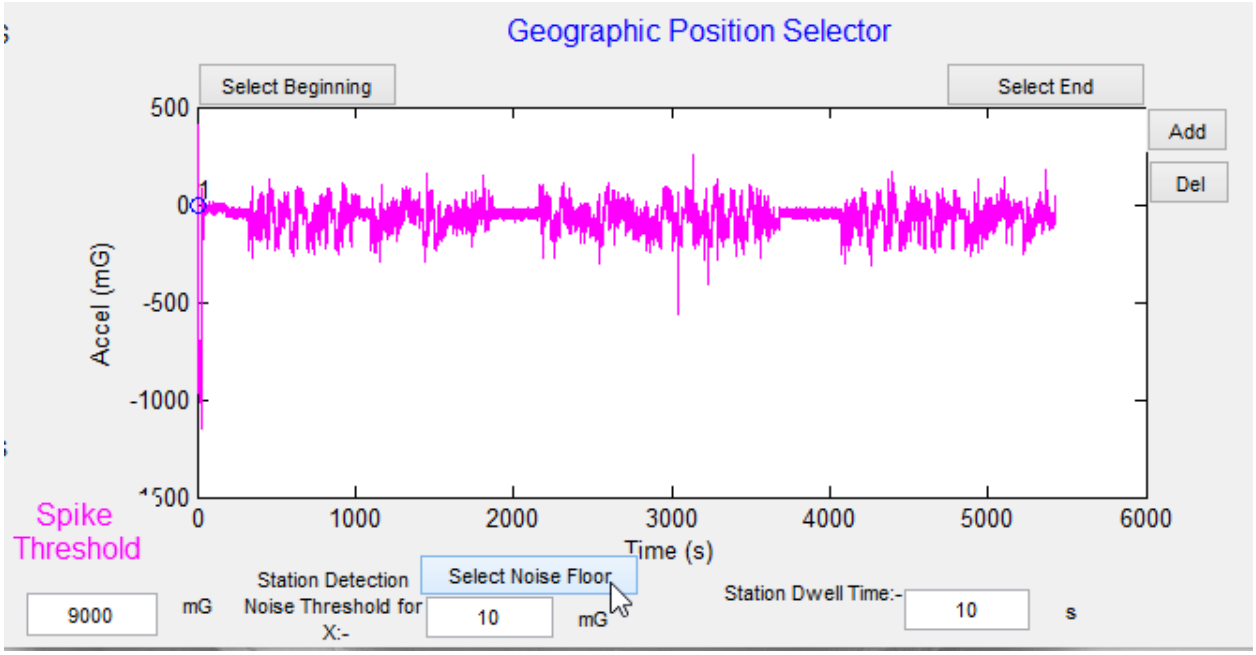


Figure 1 Noise floor selector

2.3. Click twice on the noise area to define its magnitude

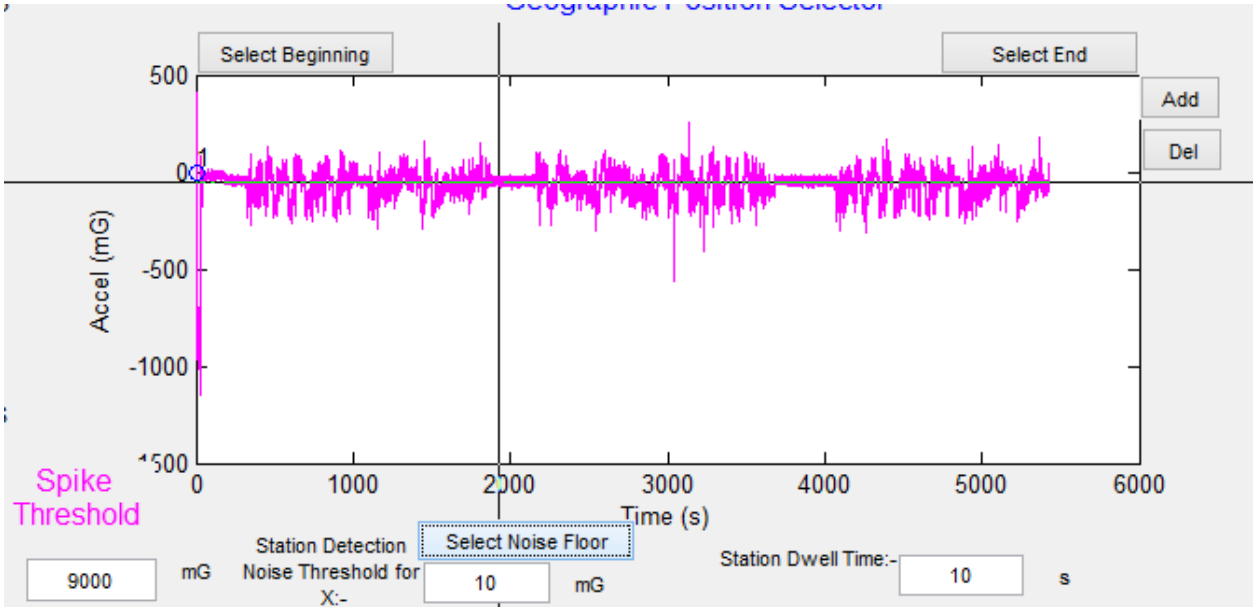


Figure 2 Noise floor selector – first mouse click

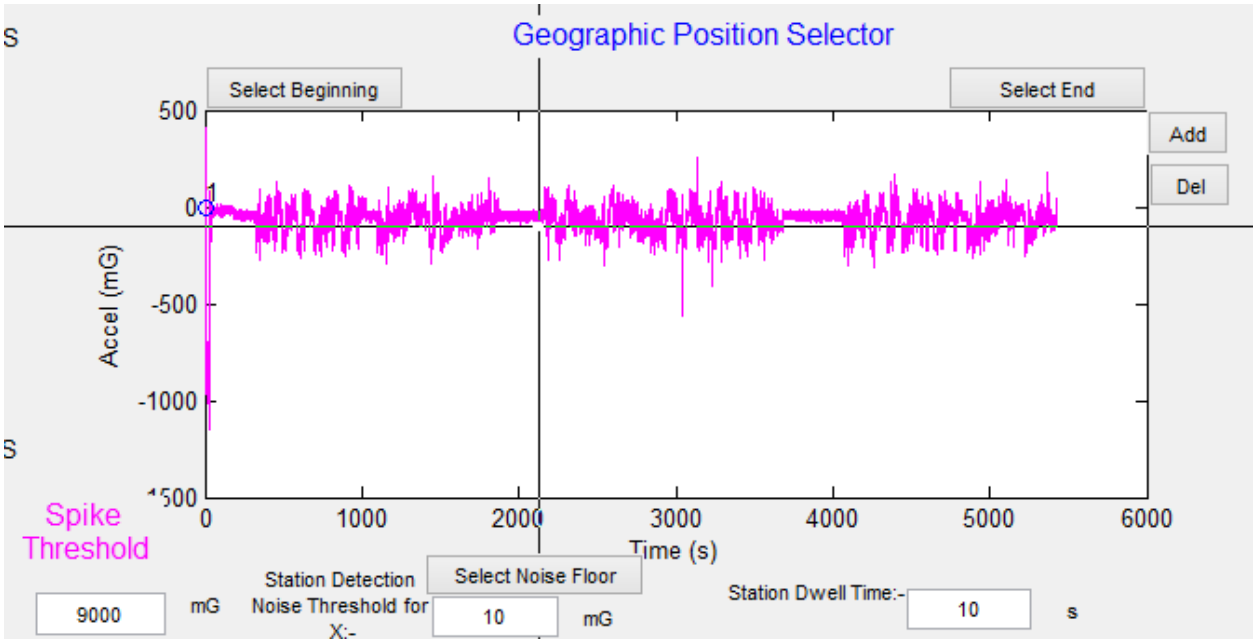


Figure 3 Noise floor selector – second mouse click

The noise floor value now appears in the "Station Detection Noise Threshold for X" cell:-

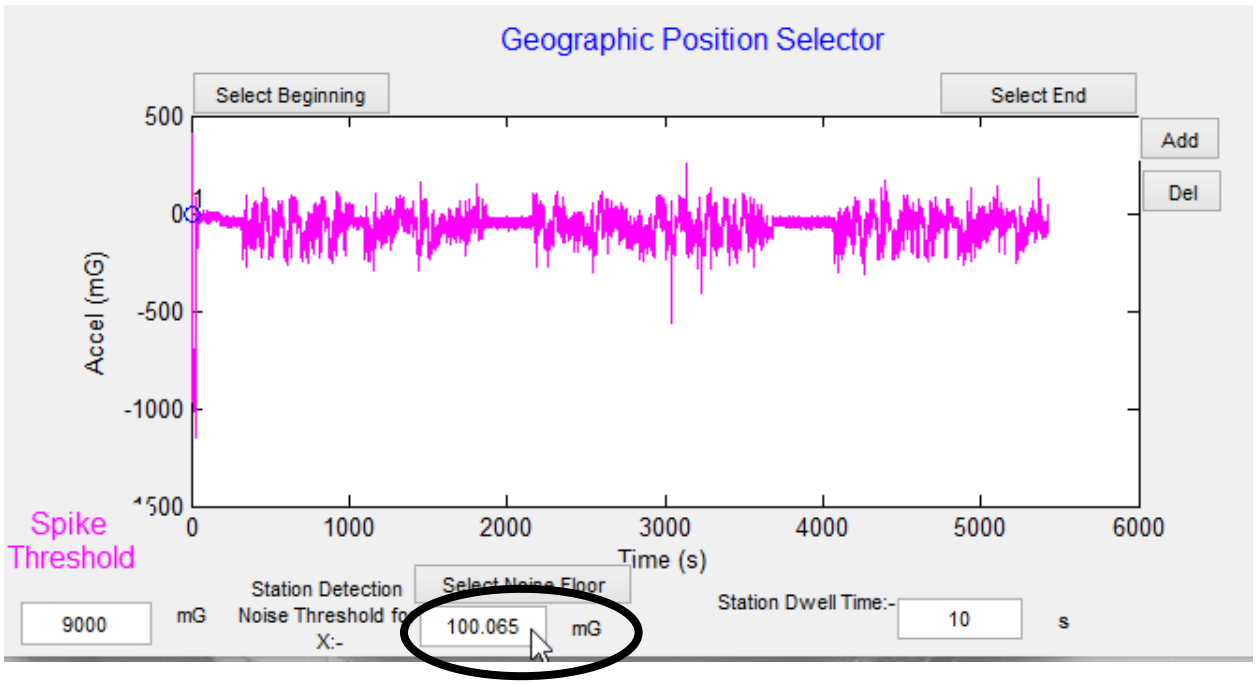


Figure 4 Noise floor selector – value calculated by software

2.4. Press update and all the stations are now automatically detected and circled below:-

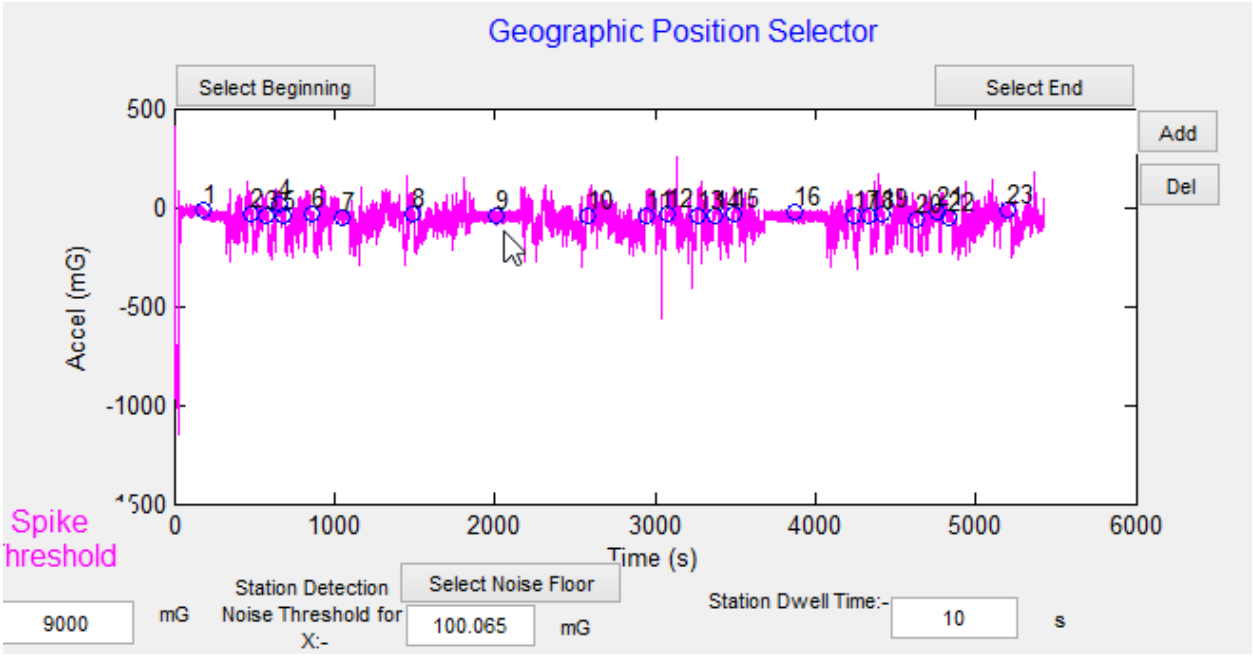
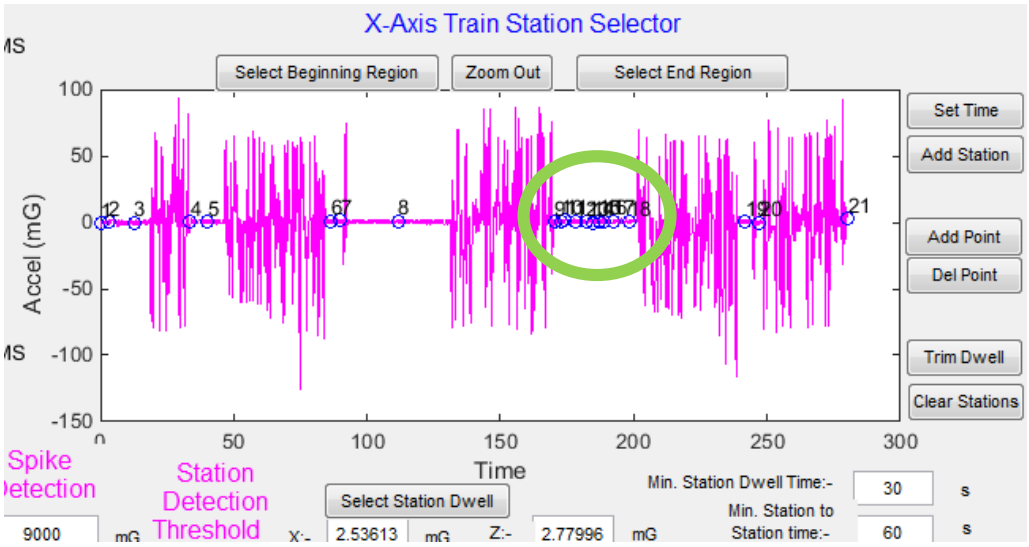


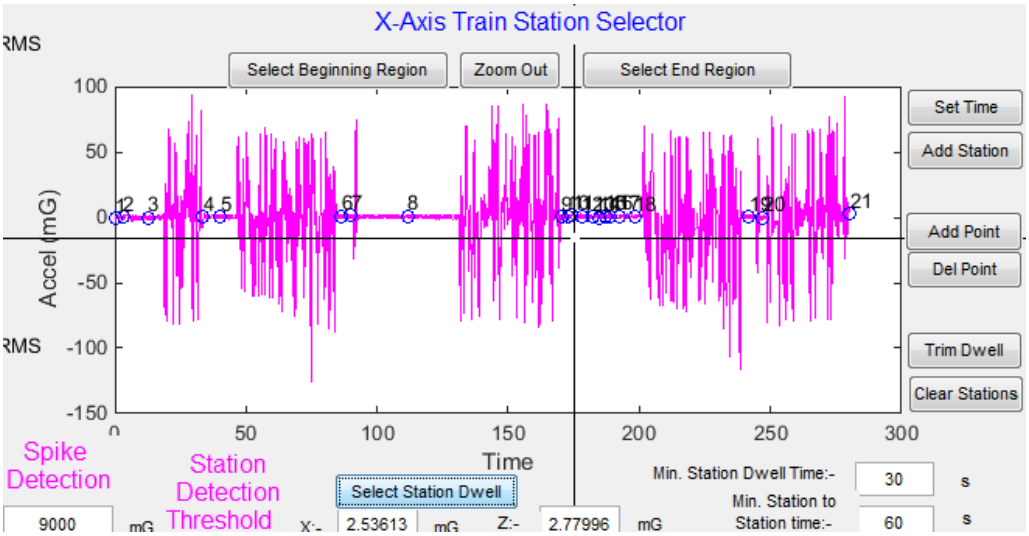
Figure 5 Automatic station selection

If there are too many stations detected e.g. here:-

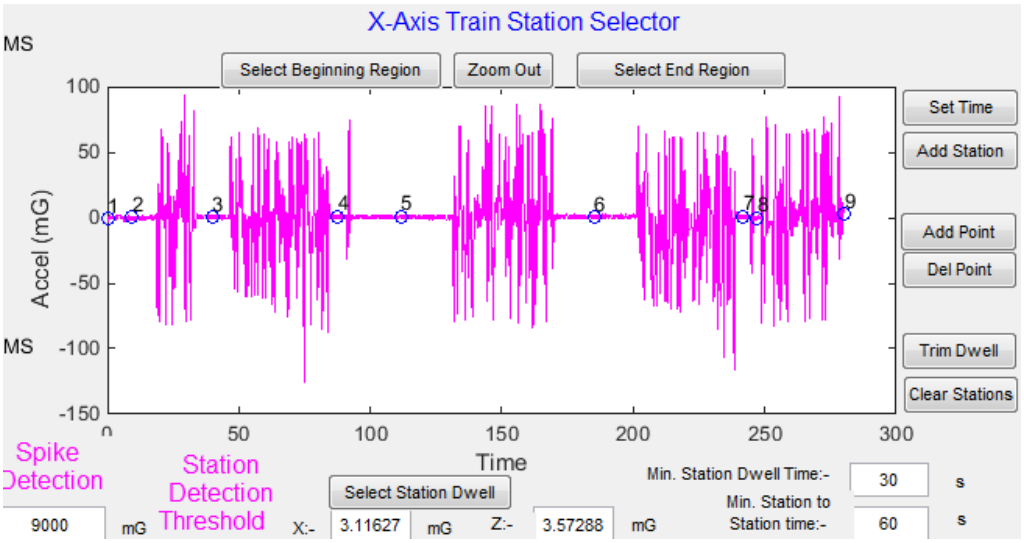


That is due to the threshold being too low.

For this case, you can use the station dwell selector below and select the dwell area with too many stations:-



The result will be quite good:-



2.5. You also have the flexible option to change the threshold value if you consider the number of stations are too many/less and add or delete stations by using the 2 buttons on the far right hand side of screen.

3. Station to station analysis

3.1. Press “select beginning” and select the 1st station in the time interval

3.2. Press “select end” and select the 2nd station in the time interval

3.3. Press update

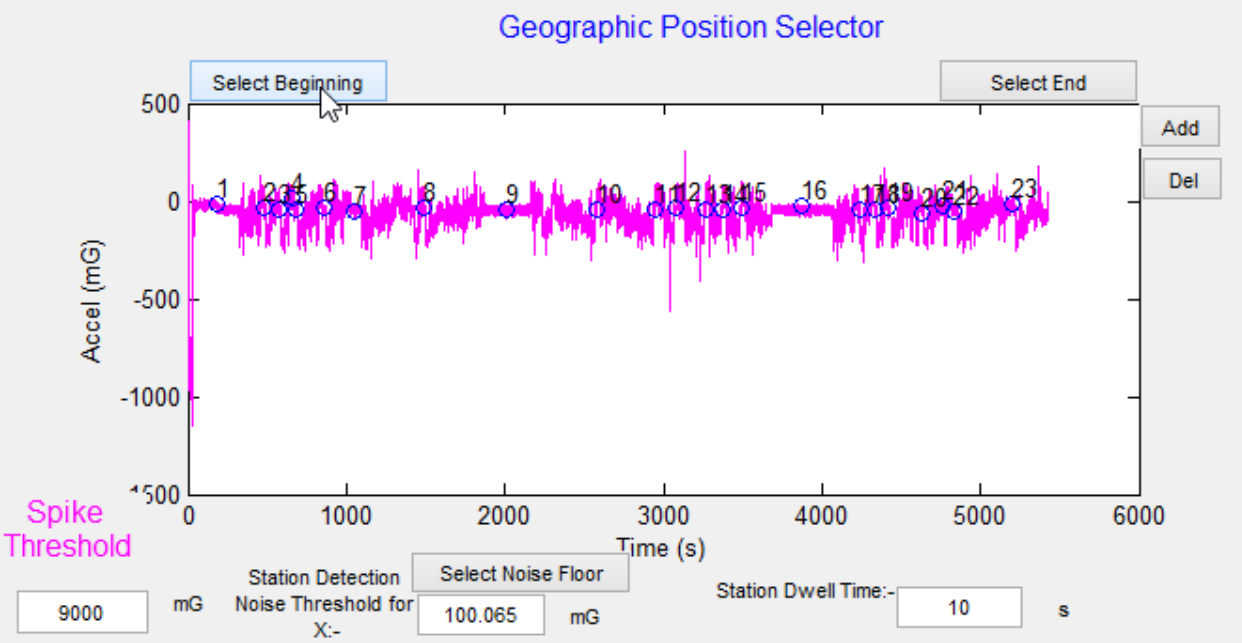


Figure 6 Automatic station selection – first mouse click to select station to station

3.4. Note that if you did tick the ISO2631 filter dialog box, it will ask which pre-filter to choose for the ride comfort analysis (all RMS will change value as a result):

3.4.1. ISO2631 which filters 0.5Hz to 80Hz in accordance with the standard.

3.4.2. MacMinder filter which ranges between 0.05Hz to 20Hz. MacMinder is a internationally used device that measures ride comfort. The values produces are usually around ½ in magnitude as the ISO2631 filter. To compensate for the reduction in magnitude, in Hong Kong trains, they use an acceptance criteria of 10mg and 13mg for vertical and lateral vibration respectively instead of the ISO2631 acceptance criteria.

3.5. You will find the graphs at the left hand side changes and all the calculations are adjusted for the station to station interval you selected. Furthermore, a frequency power spectrum plot is shown that represents the frequency spectrum for that particular analysis interval.

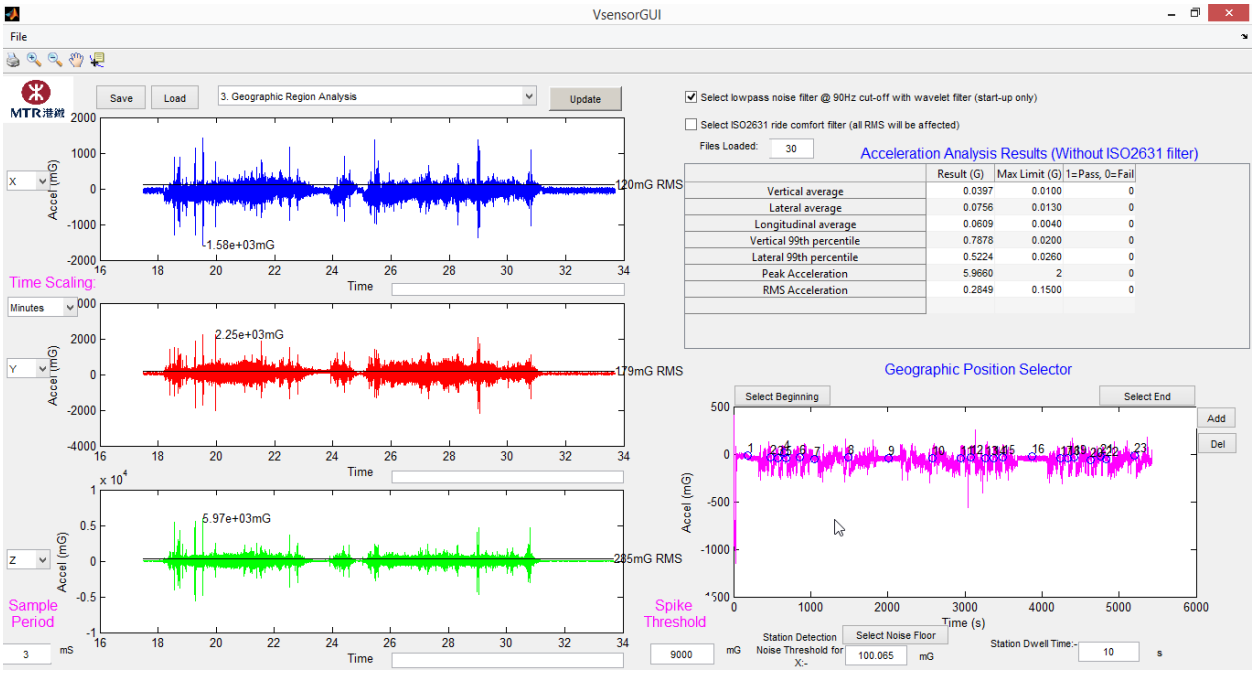


Figure 7 Station to station analysis results – average RMS calculated (example)

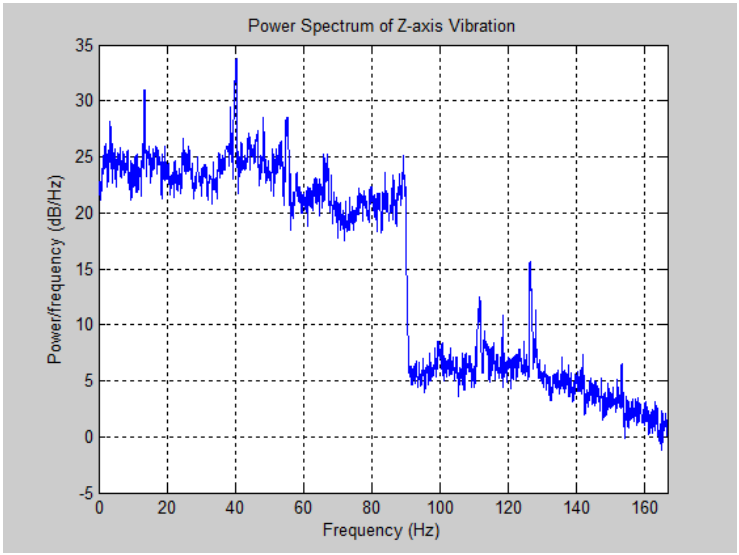
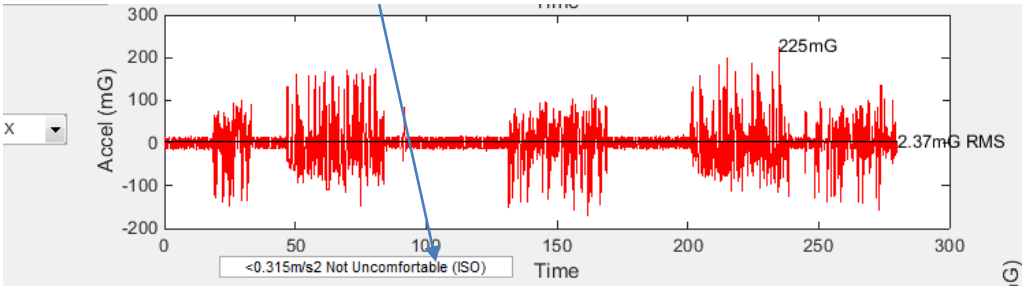
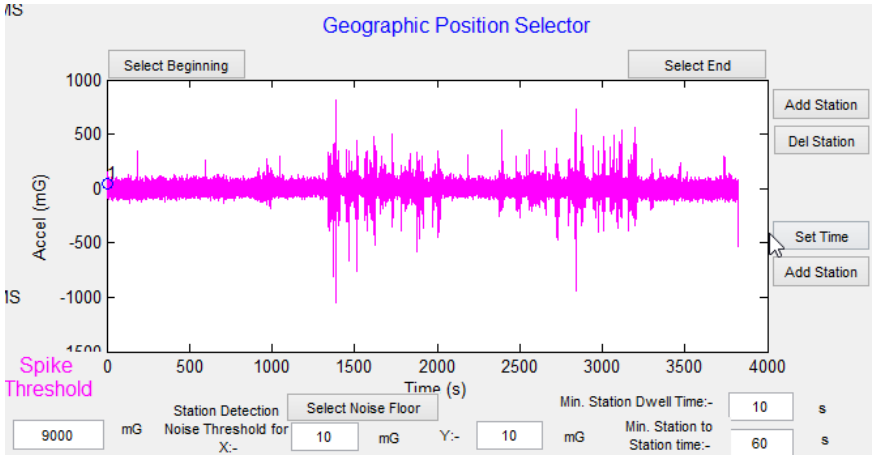


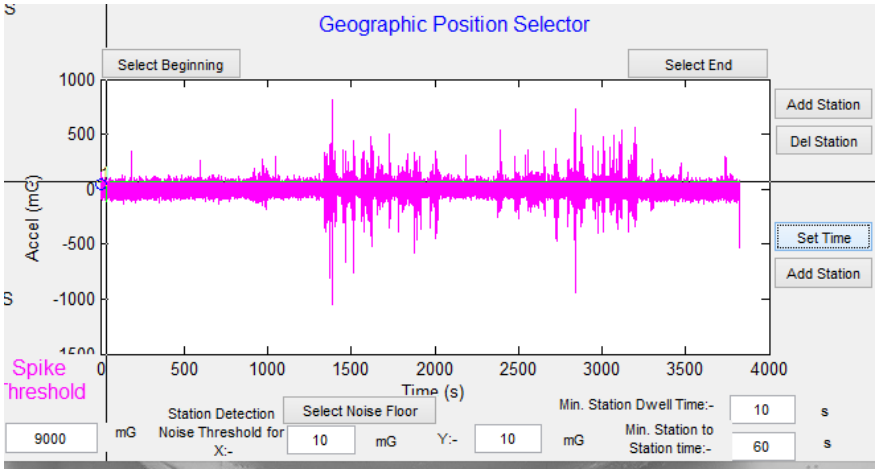
Figure 8 Station to station analysis results – frequency domain calculated (example). Note the Y axis is in dB/Hz

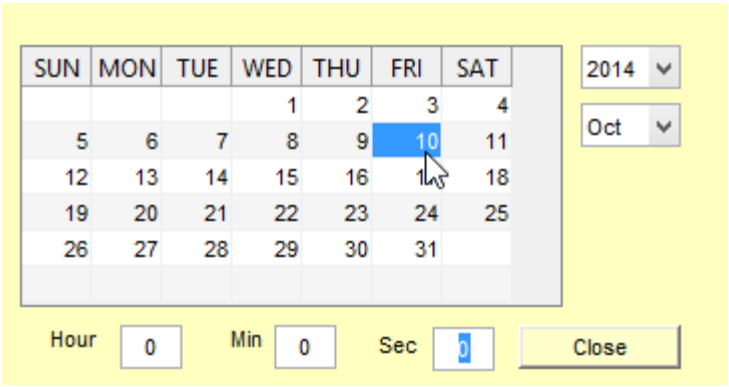
3.6. Now if you selected ISO2631, the RMS values shown on the graph will be the ones post filtered by ISO261. And there will be advice on whether they satisfy the filter criteria or not:-

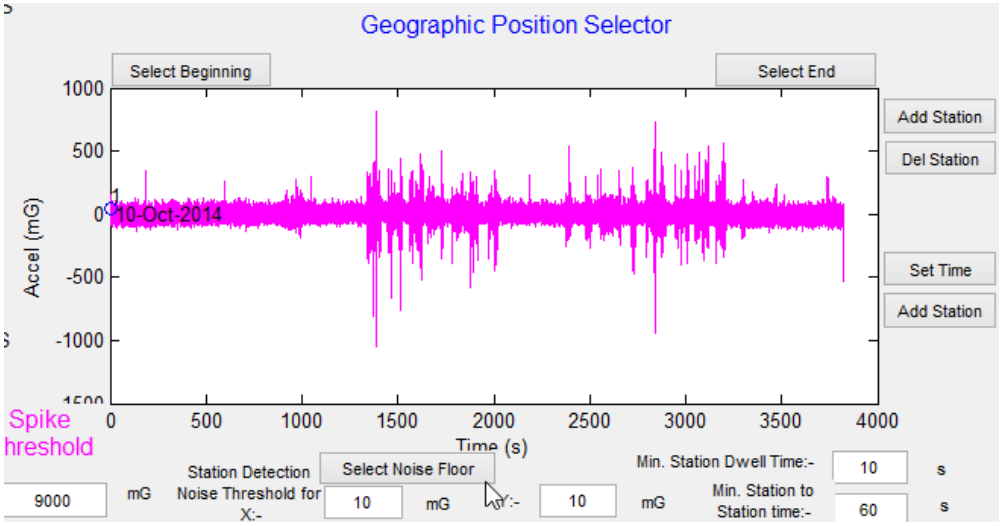


4. Manual station detection – if you have recorded down the station times manually
   4.1. Click “set time” then set any known time (it can be the start time of the data when you switched on the device or the switch off time or the time of a particular station); afterwards the entire dataset time will be known

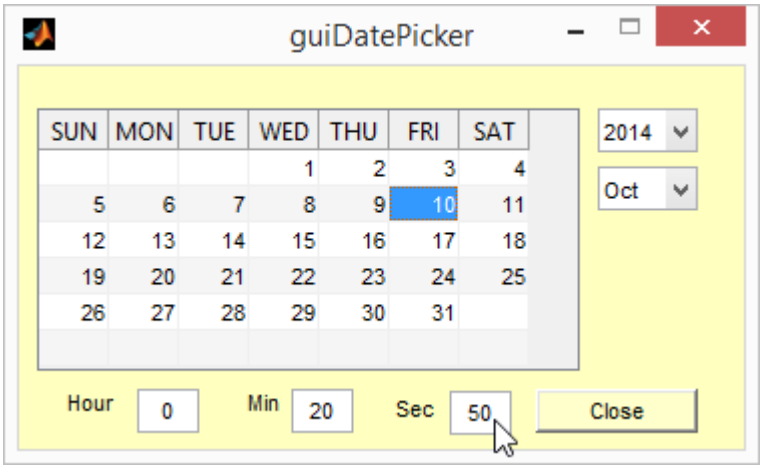


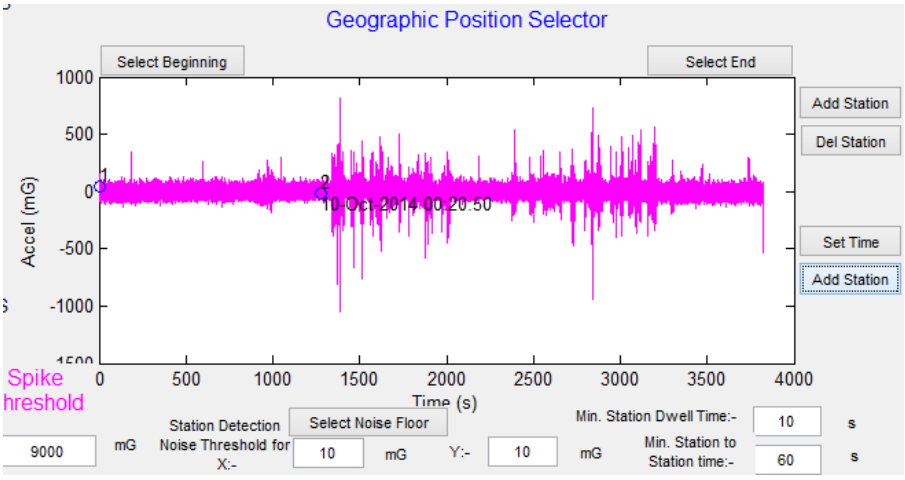






4.2. Click “add station” then set the time of the station(s) that you recorded down, the station(s) will be inserted in the correct time (for a train that stopped at a station for say 10 seconds, then assume the station time is at the 5th second).

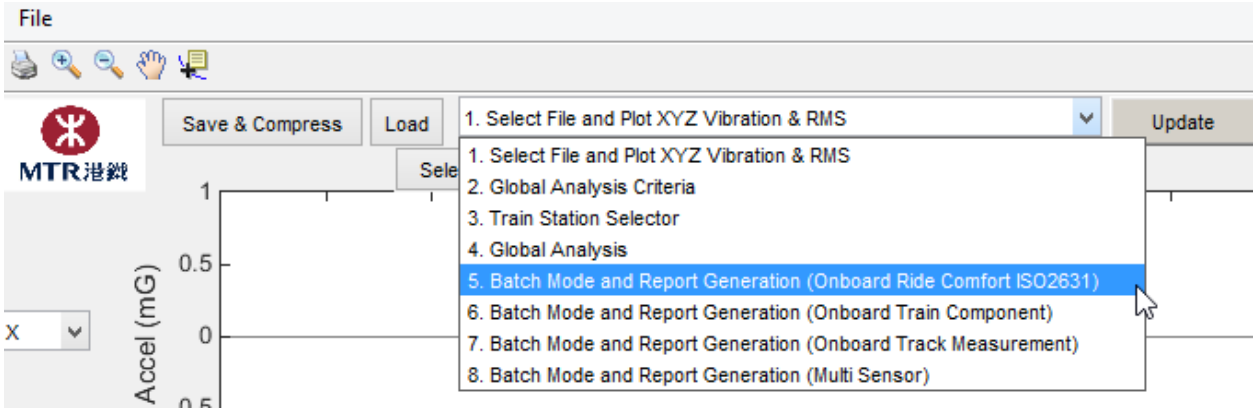




Analysis – Automatic Batch Mode Station to Station

1. This is relevant only to sensors installed onboard the train either above or below the underframe.
2. Ensure you have selected the range of stations to analyze using the train station selector analysis tool. Otherwise the analysis won't run.

3. At the top drop down menu, select Batch mode (either train saloon, train component above/below the train, or for track condition assessment).



   a) Onboard Ride Comfort assessment mainly focused on station to station analysis of **average vibration, peak vibration, and ride comfort level.**
      a. This analysis mode will ask which pre-filter to choose:
         i. ISO2631 which filters 0.5Hz to 80Hz in accordance with the standard.
         ii. MacMinder filter which ranges between 0.05Hz to 20Hz. MacMinder is a internationally used device that measures ride comfort. The values produces are usually around ½ in magnitude as the ISO2631 filter. To compensate for the reduction in magnitude, in Hong Kong trains, they use an acceptance criteria of 10mg and 13mg for vertical and lateral vibration respectively instead of the ISO2631 acceptance criteria.
   b) Onboard Train component assessment is mainly for station to station analysis of **average vibration and peak detection.**
   c) Onboard Track condition assessment is mainly focused on assessing the **average vibration for every 10 second intervals** on the vertical axis then the vibration is ranked from lowest to highest.

4. You will be prompted to save the word file:-

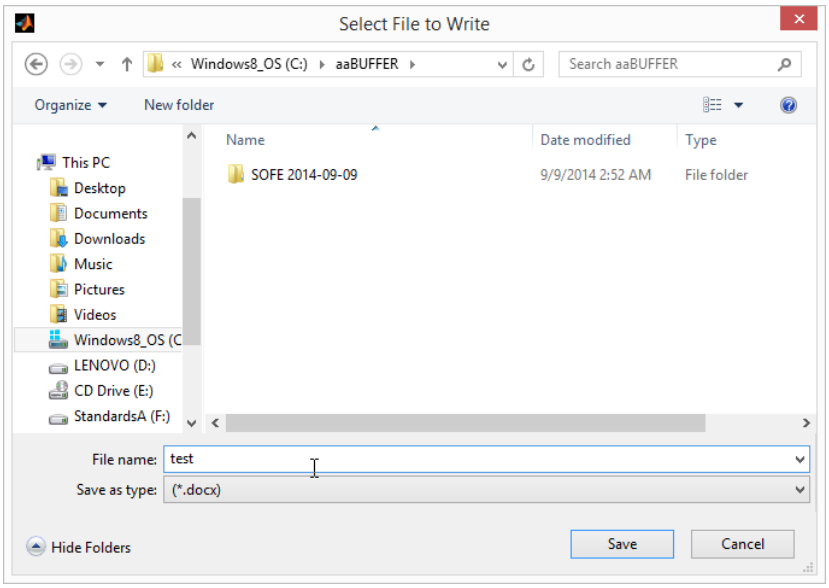


Figure 9 Word file save directory selector

5. Wait until a Microsoft Word file report is generated. The report provides:-
   a) Automatic executive summary generation
   b) An analysis of the whole trip
   c) An analysis of each station to nearby station vibration assessment based on RMS on each 3 axis, peak detection, and frequency spectrum analysis.