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Statistical Vibration Synthesizer

Background Information

Because the speed of a vehicle and the roughness of the pavement surface along a route vary, the resulting random vibrations are usually characterized by stochastic fluctuations in intensity (rms). Such nonstationary random vibrations cannot be adequately characterized with the mean Power Spectral Density function as is the case for stationary (constant rms) vibrations. Instead, they require special treatment for analysis as well as for synthesis in the laboratory.

One manifestation of the nonstationarity is that the Probability Density Function (PDF) of the overall vibrations does not conform to the Gaussian model as shown below. This effect is not produced because the vibrations themselves are non-Gaussian but, rather, because the vibrations are composed of a sequence of constant rms, Gaussian vibration segments with each segment having a different rms level and duration. It is this that causes the overall process to adopt a non-Gaussian appearance.

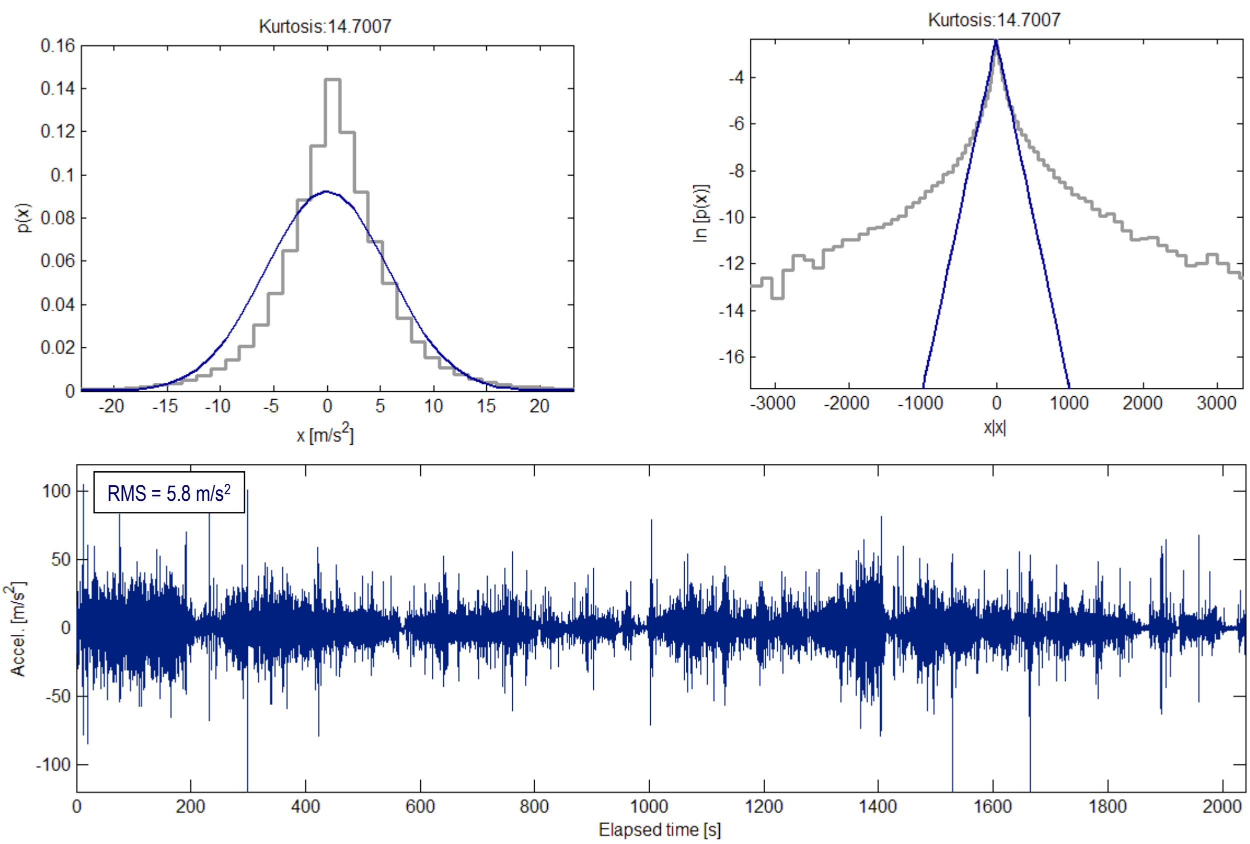

Figure 1. Typical nonstationary vibrations generated by road vehicles.

This approach of treating nonstationary vibrations as a sequence of Gaussian segments is exploited by the **Statistical Vibration Synthesizer** system to enable the conversion of ordinary Random Vibration Controllers (RVC) into systems capable of reproducing realistic, nonstationary vibrations.

As an example, for the case shown in figure 1, the vibrations produced by an ordinary RVC is based solely on the mean PSD and, consequently, result in constant rms vibrations as shown in Fig. 2. The PDF of these vibrations confirm that they are Gaussian. Given that the overall rms level of the simulated vibrations is the same as that of the measured vibrations, the most striking difference is the absence of the fluctuation in vibration levels. Peak values on the simulated Gaussian vibrations never exceed 18 m/s^2 (depending on the configured value of the maximum crest factor – also known as sigma-clip) compared to peak value exceeding 100 m/s^2 from the measured vibrations. This dramatic deficit must have significant consequences on any validation tests carried out using ordinary RVCs.

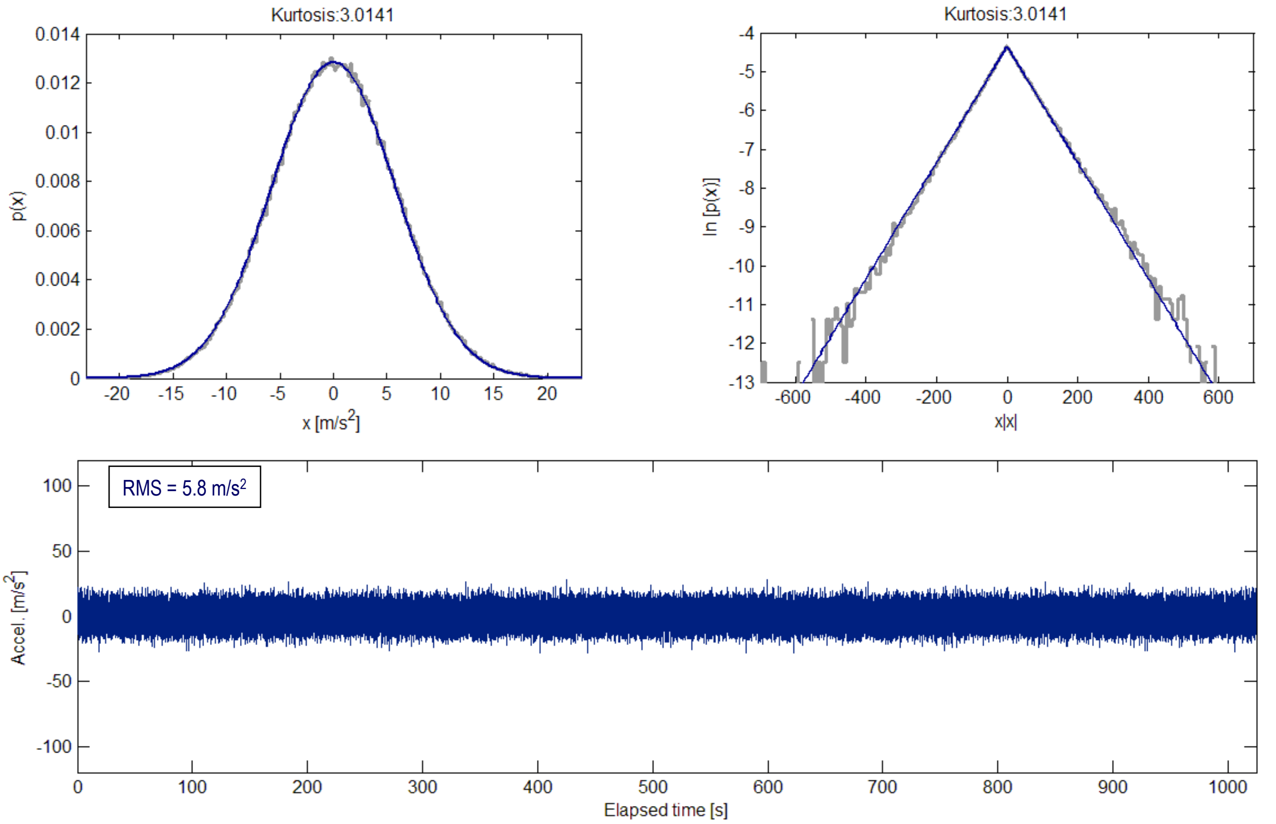

Figure 2. Typical stationary vibrations produced by ordinary Random Vibration Controllers (as generated from the PSD of the vibration data shown in Fig. 1).

The main distinction of the **Statistical Vibration Synthesizer** system is that, in addition to the mean PSD, it uses an rms distribution (preferably computed from measured vibrations) to create the nonstationary effect. The PSD and rms distribution functions are combined in such a way as to statistically reproduce the stochastic fluctuations in rms level that are inherent to the original vibrations. In other words, the SVS system uses not only a target PSD but also a target rms distribution as shown in Fig. 3.

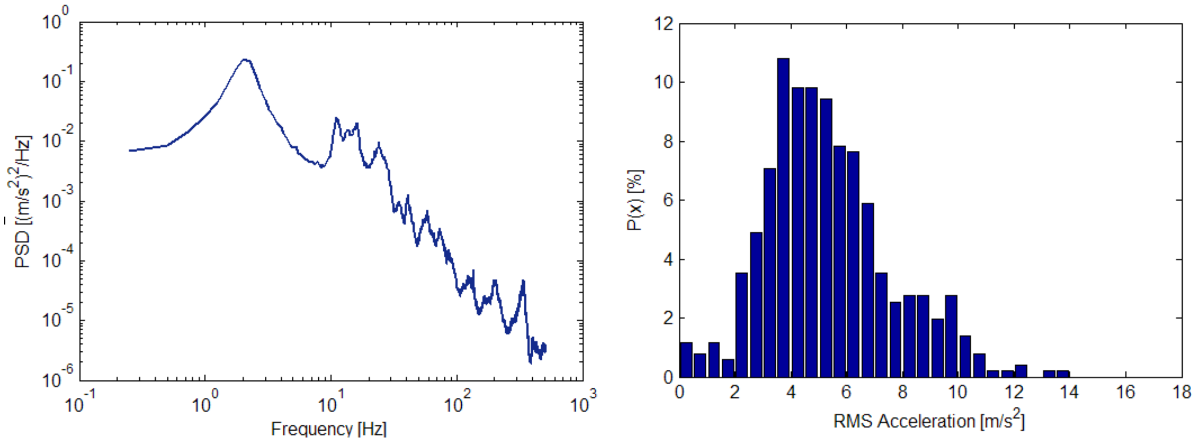

Figure 3. The mean PSD (left) and rms distribution (right) for the vibration record shown in Fig. 1.

When the spectral and rms distribution functions are combined, the resulting synthesized vibrations possess a distinct nonstationary character that is similar to that observed in measured vibrations. When compared with stationary (constant rms) random vibrations produced by ordinary RVCs, the difference is striking especially when one considers that the rms level is exactly the same. In the case illustrated below, the maximum acceleration achieved by the SVS is approximately 85 m/s^2 which compares well with the maximum of the measured vibrations. By contrast, the vibrations produced by an ordinary RVC is approximately 50 m/s^2 (slightly above 3 x rms).

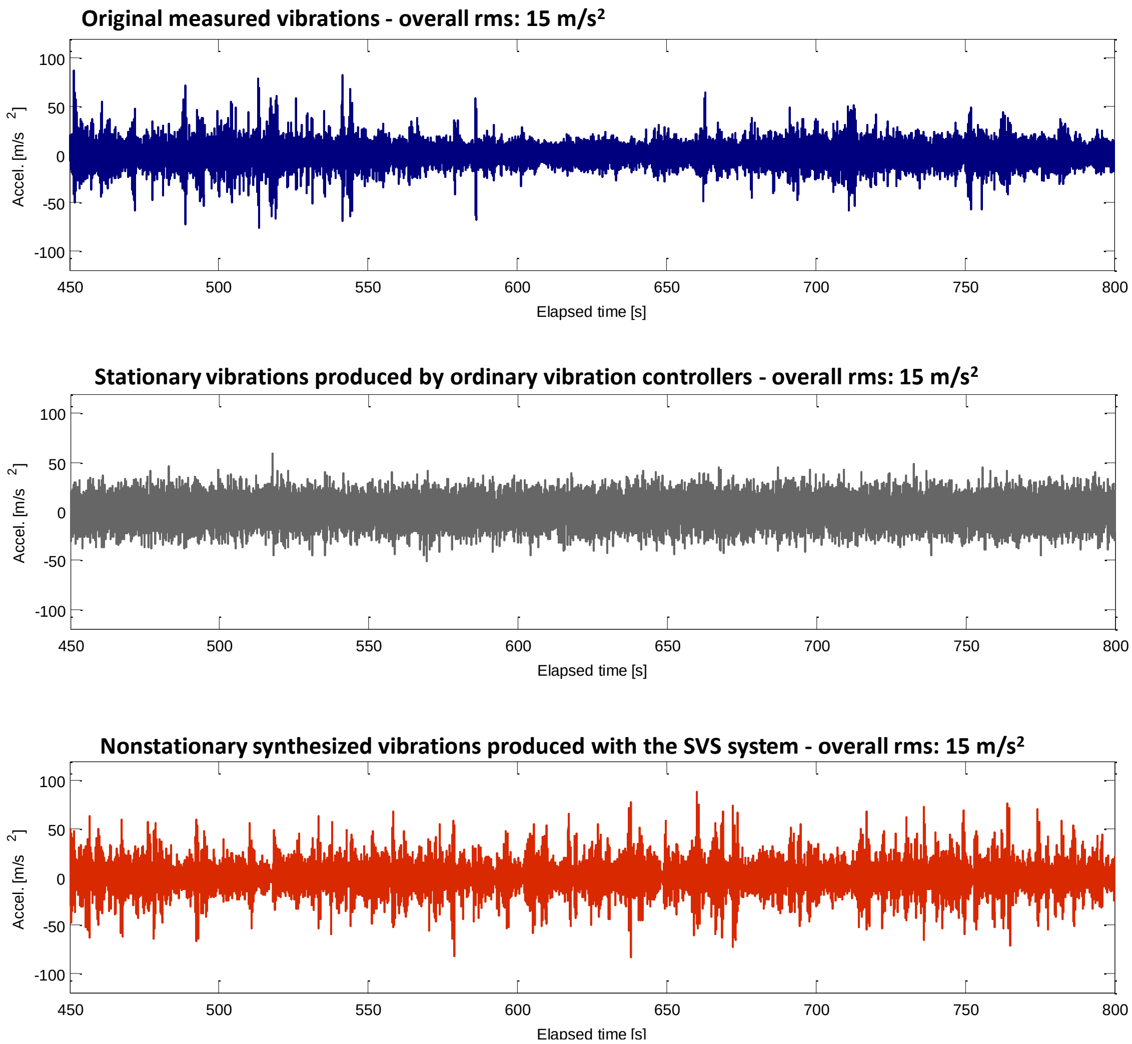

Figure 4. Typical case comparing vibrations produced by an ordinary Random Vibration Controller (center) with those produced by the Statistical Vibration Synthesizer system (bottom).

In statistical terms, vibrations produced by the SVS system conform to both the target PSD as well as the target rms distribution as shown in Fig. 5 (top right and bottom left respectively). In addition, because there exists a relationship between the rms distribution and the PDF of the random vibrations, the target PDF can be calculated and shown along with the synthesized vibrations at bottom right of Fig. 5. Also shown in black is the equivalent Gaussian distribution.

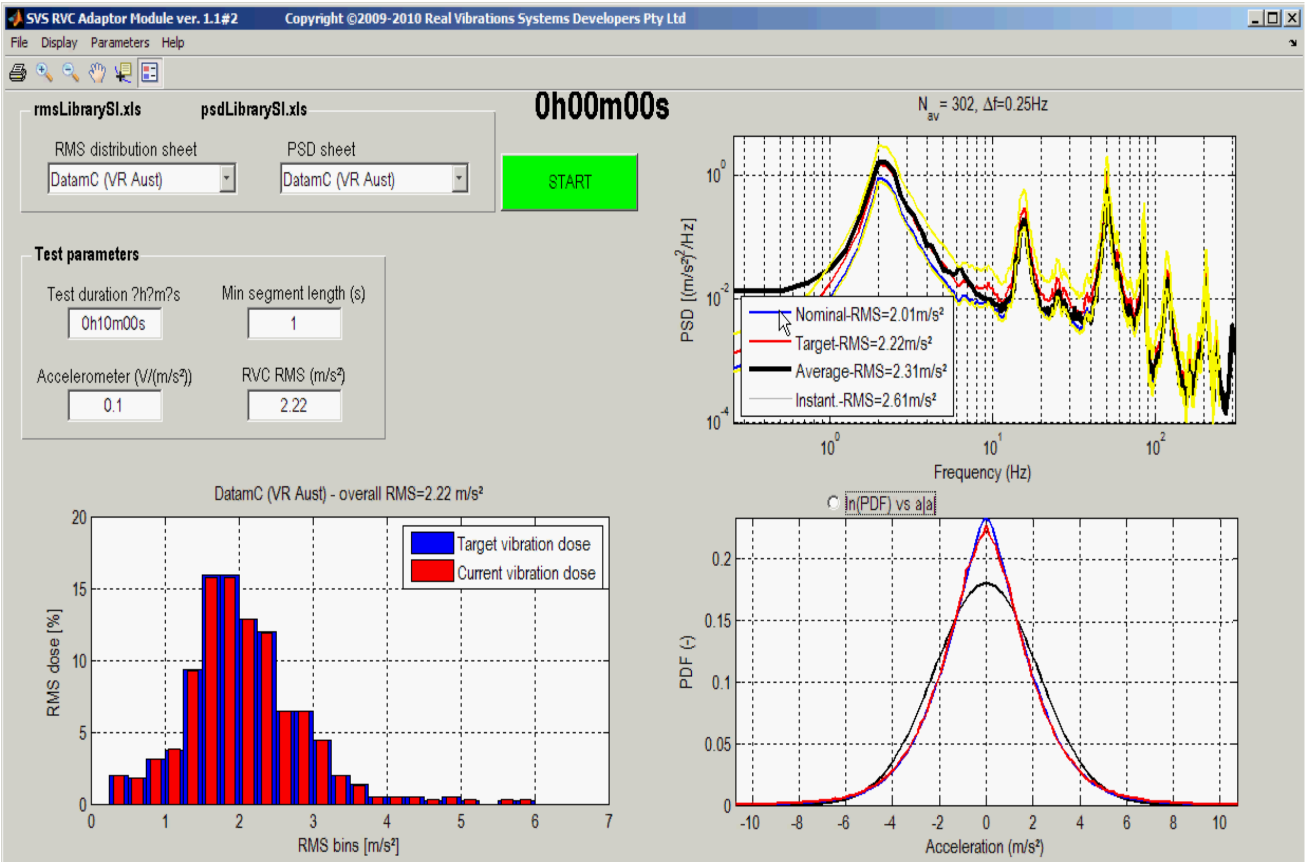

Figure 5. Typical spectral and statistical functions from nonstationary vibrations produced by the Statistical Vibration Synthesizer system (screen shot from actual SVS system).

References:

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