DOES EMI SHIELDING INCREASE VIBRATION?

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09.14.2017

Overview: As metrology and research tools continue to improve in functionality and measurement resolution, they become more sensitive to environmental changes including electromagnetic interference (EMI), vibrations and acoustics. While the OEMs design their equipment to minimize the potential impact of environmental disturbances, it is impossible to design the equipment to meet all environmental conditions. Therefore, it is critical that these requirements are accounted for when designing a space to accept such equipment. This paper shows that a well thought out design can mitigate the potential interference of an unfavorable environment, including increased vibration caused by poorly designed shielding

Designing EMI Shielding for Vibration: Field Management Services (FMS) recently participated in the design and construction of the IMRI (Irvine Material Research Institute) electron microscopy facility at UC-Irvine, which houses some of the premier electron microscopes on the market. While FMS' main design scope was to address the EMI environment, it was critical that the design team ensured that all solutions for environmental concerns were fully integrated to achieve all environmental requirements.

The environment and design requirements at UCI demonstrated a clear need for EMI mitigation, including six-sided EMI shields. Of major concern was the relationship between the EMI shielding design/installation and its possible contribution to building vibrations. This concern was raised by the microscope OEM based upon a prior project experience.

In installations involving sensitive equipment, a design team will often go to great lengths to minimize vibrations from sources including traffic, seismic, building mechanicals and an assortment of other possible sources. Solutions could include specific construction methods like increasing the thickness and stiffness of the slab, isolated slabs, slabs constructed on isolation springs, elastomeric bearings, and active vibration isolation tables, to name a few. In addition to slab construction, a design needs to consider what additional construction will be required on the slab. Adding materials on the slab (like shielding, floor finishes, and loading of the slab) can alter the vibration characteristics of floor systems and can increase vibrations. For this reason, the effects of all possible materials, including shielding, were considered in the final design. Similarly, the UCI team optimized the support facilities to mitigate any possible adverse vibration effects, including isolated slabs in each lab and a sophisticated passive vibration isolation table for one of the electron microscopes.

Examining the Effects of Shielding. First, the design team considered the elasticity of the shielding material. Fortunately, shielding is typically comprised of rigid materials like aluminum, copper or steel; there is only limited concern that the material itself will alter the vibration characteristics of the completed flooring system. However, the design team needed to consider how the construction methodology might impact floor vibrations. Any "puckering" or "oil canning" of the material during installation could create a spring response, which could increase the vibration characteristics of the floor system. "Puckering" is defined as a tight gather of material at plate edges or near fasteners that can create deformations, lifting the shielding from the underlying substrate and introducing unintended "springs". "Oil canning" is defined as a buckling of sheet material and can result in a snap-like deformation of the material that can create vibrations. To avoid the potential for "oil canning" or "puckering" the design team established a minimum critical floor flatness specification of 1/8" over ten feet and required that the material be sufficiently anchored to the slab.

Example of shielding application that amplified vibrations. The shielding was comprised of aluminum, silicon steel, and low carbon steel. The shielding had to be cut to create pads for the equipment allowing the equipment to sit directly on the concrete slab. This resolved the vibration issue, but reduced the effectiveness of the shielding.

Common materials utilized for EMI shielding include aluminum and silicon steel with different vibration effects. The aluminum is typically ¼" thick, which means the material is rigid and, if anchored correctly, will limit the potential for the material to exhibit an "oil can" effect. Silicon steel, on the other hand, comes in thin sheets (thicknesses of 0.014 - 0.025") and requires multiple layers to achieve the desired shielding effects. Silicon steel can negatively impact vibration if not effectively installed to avoid the potential for both "puckering" as well as "oil canning" between layers. The installation crew also needed to be diligent during installation to avoid "puckering" when welding aluminum or steel. The welding process can cause warping of the plates, causing the seams to "pucker". Worse, individual plates can exhibit a spring effect where the plates pucker, and if the welds are insufficient, they can break.

Testing Shielding/Vibration. As in any major project for which specifications must be met, the University required confirmation of performance through EMI performance testing and vibration stress tests in the subject laboratories. For confirmation of vibration performance, an outside, independent vibration and acoustics consultant, Vibrasure, was contracted to perform the tests. Using standard professional vibration test equipment, a test procedure was developed collectively by UCI, the EM manufacturer, Vibrasure and FMS to confirm that:

1. The shielded rooms met the individual instrument vibration specifications, and
2. The addition of shielding did not materially affect the vibration performance of the room.

At the time of testing, the EM suites were largely complete, with equipment installed in the instrument rooms. Thus, an area near the center of each electron microscope room was prepared to expose an area of underlying concrete and an area of shielding. This allowed comparative measurements for three floor conditions:

1) subfloor/concrete (alone)
2) concrete plus shielding, and
3) concrete plus shielding plus final floor finish.

Those measurements included Fast Fourier Transforms (FFTs) from DC to 100Hz and were collected simultaneously for the 3 floor conditions, under 3 separate stress conditions:

1) background/ambient conditions (no forcing),

2) purposeful forcing in the control rooms located adjacent to the microscopy rooms, and
3) purposeful forcing in the microscopy rooms.

“Purposeful forcing” for these tests is defined as continuous “rolling office chairs, walking and heel drop by a full-scale engineer”.

Each spectrum is an average of 48 observations over a period of 240 seconds. To ensure a high sensitivity to transient events that may have been caused by the shielding, a narrowband FFT was used with each observation representing a five second average.

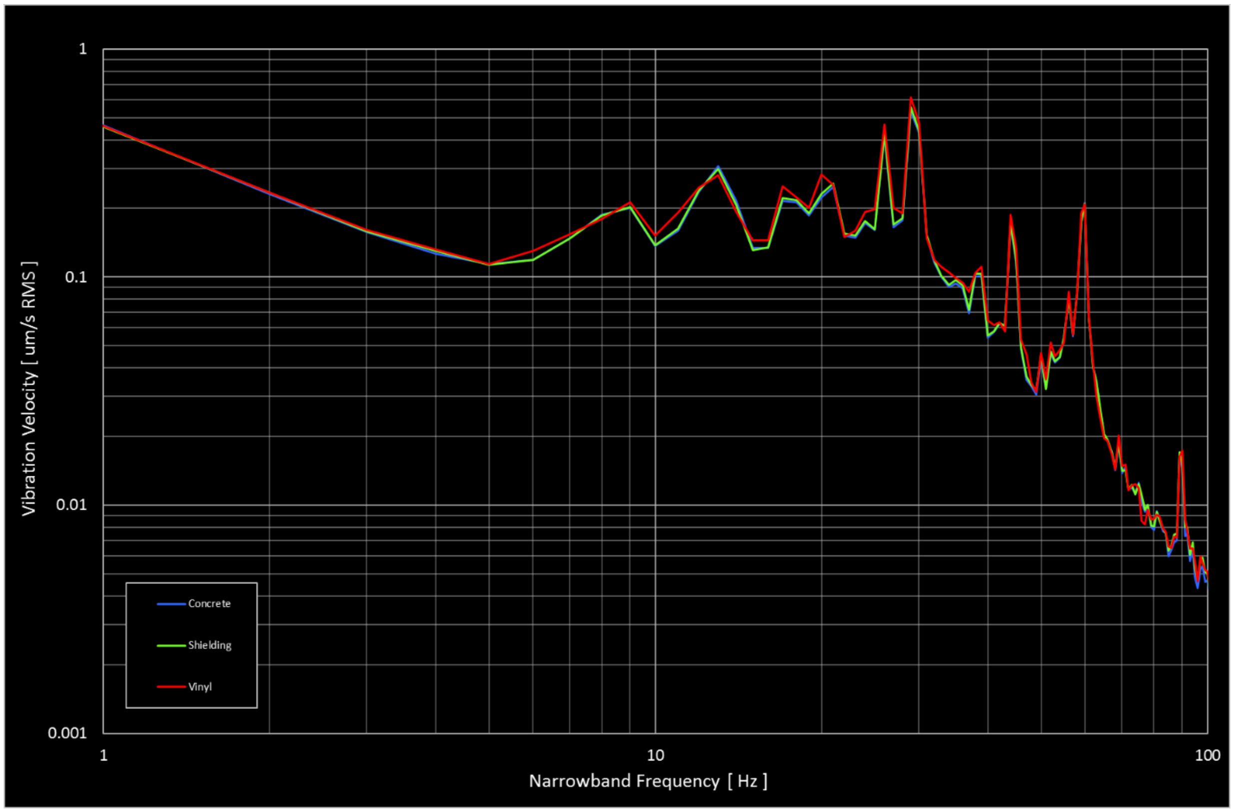

Figure 1 Spectral data from STEM-4 (JEOL JEM-2800), in Ambient / Background Condition. Data collected at locations noted in figure legend. The maximum-observed 1/3 octave band velocity = 0.98um/s RMS in the 25Hz band, meeting the VC-F criterion, meeting the VC-E criterion of 3.1um/s by a wide margin. Each spectrum is the average of 12 independent observations over the course of 60 seconds. Measurement Parameters: narrowband FFT (df = 1Hz; bandwidth = 1Hz). Each observation is a 5-frame (5-second) average, resulting in high sensitivity to transient events, which might be important to some forms of shielding influence. No windowing or overlap was used so that transient timing issues would be irrelevant in cases where multiple DAQs were deployed.

Under ambient conditions with activity restricted in the microscopy suite and control rooms, the maximum "shielding gain" – the amplification presumably introduced by the shielding – was 0.4 dB for higher frequencies and 0.2 dB for mid to lower frequencies, where the instruments tend to be more sensitive to vibrations. These figures are close to the experimental precision available in this test and are indicative of no practical effect. In fact, while the *maximum* shielding gain that was observed was less than 0.4dB across the spectrum, the *average* shielding gain (between different experiments) was close to zero.

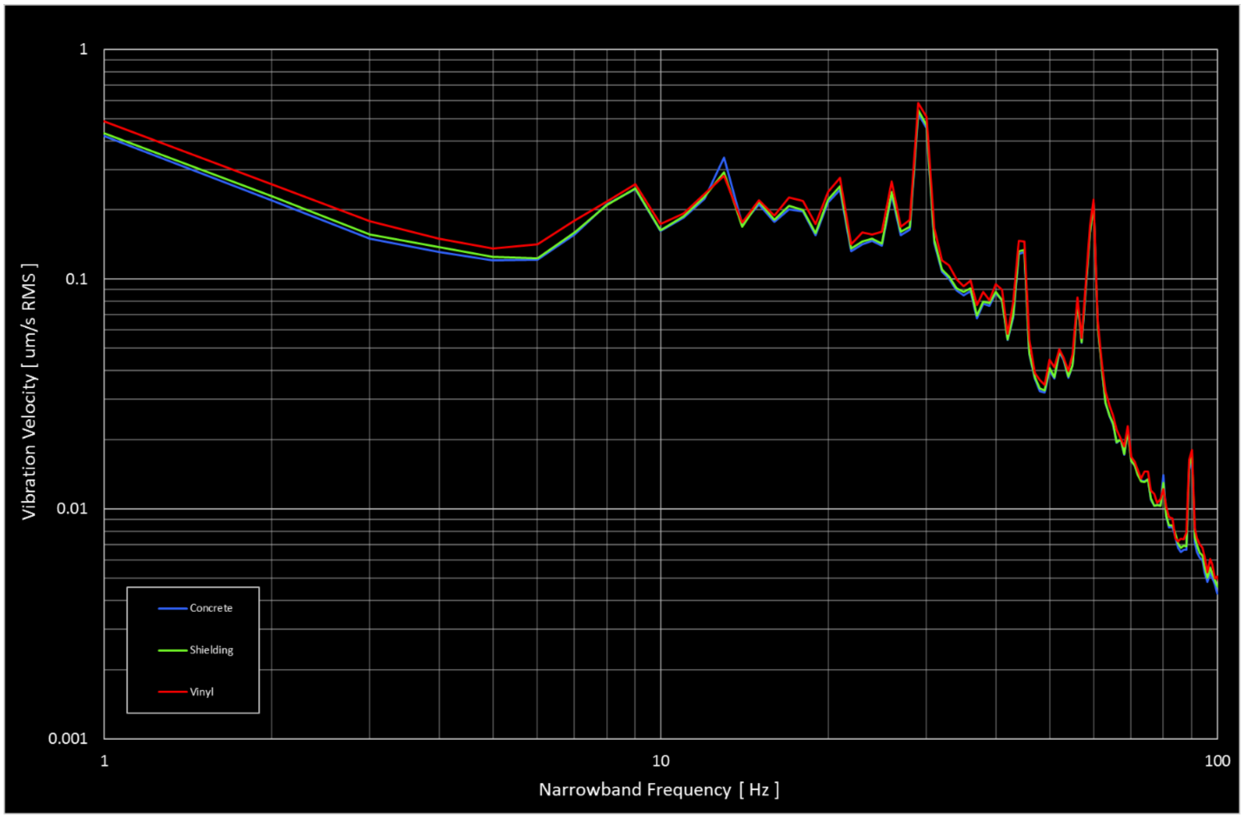

Figure 2 Spectral data from STEM-4 (JEOL JEM-2800), activities in Control Room (walking, chair roll, heeldrops). Data collected at locations noted in figure legend. The maximum-observed 1/3 octave band velocity = 0.89um/s RMS in the 25Hz band, meeting the VC-F criterion, meeting the VC-E criterion of 3.1um/s by a wide margin. Each spectrum is the average of 48 independent observations over the course of 240 seconds. Measurement Parameters: narrowband FFT (df = 1Hz; bandwidth = 1Hz). Each observation is a 5-frame (5-second) average, resulting in high sensitivity to transient events, which might be important to some forms of shielding influence. No windowing or overlap was used so that transient timing issues would be irrelevant in cases where multiple DAQs were deployed.

A second set of measurements was conducted under purposeful forcing in the control room. Again, the observed shielding gain was 0.4 dB for higher frequencies, and 0.2 dB for mid to lower frequencies, while the average gain was very close to zero. This represented essentially identical gains to ambient conditions.

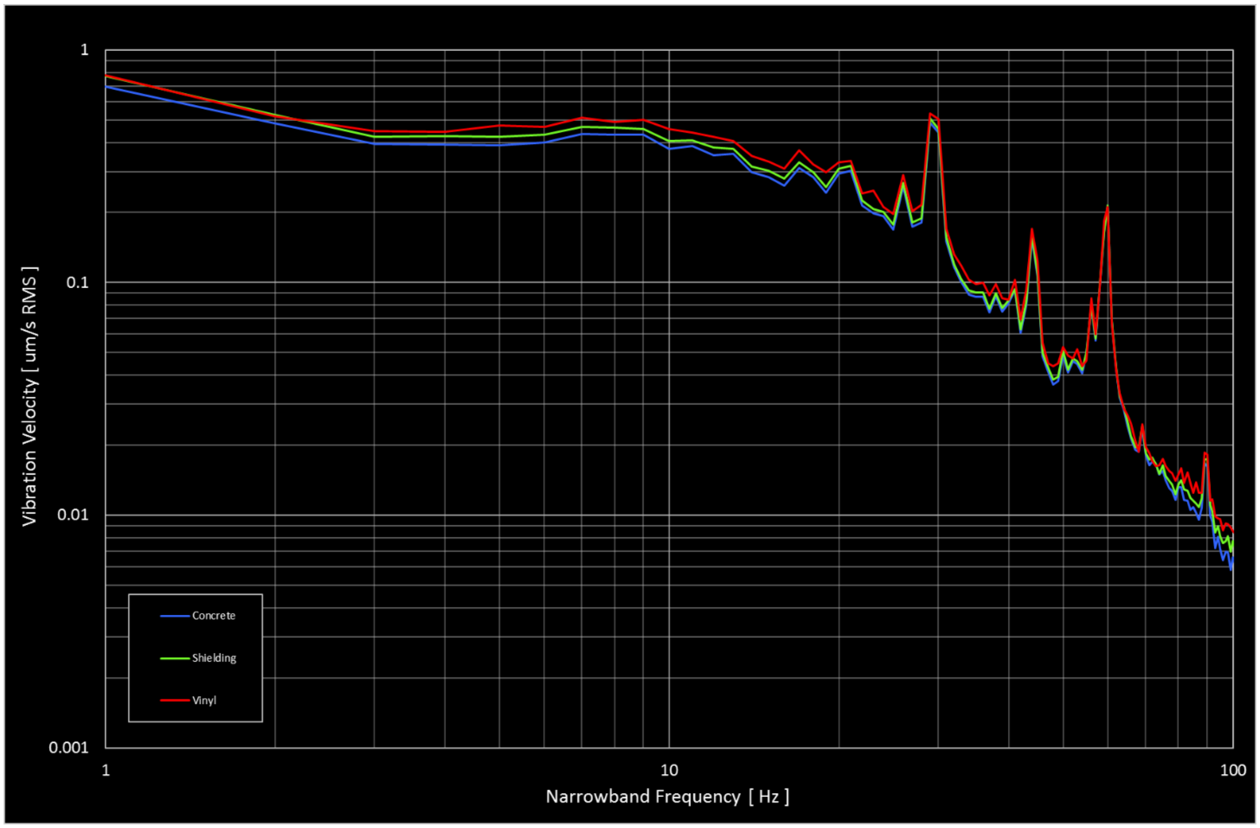

Figure 3 Spectral data from STEM-4 (JEOL JEM-2800), activities in Instrument Room (walking, chair roll, heeldrops). Data collected at locations noted in figure legend. The maximum-observed 1/3 octave band velocity = 0.88um/s RMS in the 25Hz band, meeting the VC-F criterion, meeting the VC-E criterion of 3.1um/s by a wide margin. Each spectrum is the average of 48 independent observations over the course of 240 seconds. Measurement Parameters: narrowband FFT (df = 1Hz; bandwidth = 1Hz). Each observation is a 5-frame (5-second) average, resulting in high sensitivity to transient events, which might be important to some forms of shielding influence. No windowing or overlap was used so that transient timing issues would be irrelevant in cases where multiple DAQs were deployed.

A final set of measurements was recorded under purposeful forcing inside the microscopy room. The maximum-shielding gain was 1.0 dB for higher frequencies and 0.7 dB for mid to lower frequencies, while the average gain was less than 0.4dB across the spectrum, similar to the ambient and forced control room results.

It should be noted that under normal operating procedures, this type of purposeful forcing, whether inside or outside of the instrument room, would be prohibited during operation of the electron microscope.

The measurements demonstrate that the shielding does not contribute in a significant way to the vibration response of the floor system. Indeed, the vinyl flooring appears to amplify vibrations more than the shielding, but the complete floor system of concrete slab, shielding, and vinyl flooring still did not exhibit significant increases of vibrations from layer to layer.

Summary of Results and Recommendations: As noted in this study, there have been examples where shielding did have an impact on vibration performance. In some of those cases, owners have cut holes in the shielding so that the instrument sits directly on the concrete, but they do so at the cost of a sacrifice in shielding effectiveness. However, extensive measurements at UC Irvine clearly demonstrate that if a shielding system is properly designed and installed, any impact it may have on the vibration performance of the room will be inconsequential and of little concern to performance of the microscope.

The data in this case indicate that other features of the environment – unrelated to shielding – may limit vibration performance but the shielding is irrelevant.